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A RAND NOTE

Material Problems at a Naval Aviation Depot:
A Case Study of the TF-30 Engine

Lionel A. Galway

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A RAND NOTE

N-3473-A/USN

Materiel Problems at a Naval Aviation Depot: A Case Study of the TF-30 Engine

Lionel A. Galway

Prepared for the
United States Navy

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PREFACE

In November 1989, RAND presented a series of hypotheses and results from exploratory research to a group of senior Naval logisticians at the Naval Postgraduate School, Monterey, CA, as the basis of a proposed project on Naval aviation logistics. The proposed project was to consider how lessons learned in previous RAND logistics research might apply to the Naval aviation logistics system, particularly the operation of the Naval aviation depots (NADEPs), and to consider how the detrimental effects of uncertainty on mission capability, particularly in wartime, might be offset by management adaptations.

One of the most pressing problems discussed at the meeting was how to supply repair parts to the NADEPs in a timely fashion. It was decided that one part of the project would focus on this "materiel problem" in an attempt to understand its dimensions and to arrive at possible solutions. This Note documents that research, which is expected to be of interest to logisticians, depot managers, and materiel support personnel in all parts of DoD.

This work was done as part of the project *Enhancing the Logistics System: The Depot Perspective*, sponsored jointly by the Navy Secretariat, NAVAIR-43, and NAVSUP. It builds on efforts begun earlier on this project, some of which are still in progress. James Hodges and Judith Payne initiated the TF-30 case study and did a substantial amount of the preliminary work on which this study was built. Daniel Relles formulated a variant on an idea used here as part of a study he is conducting with Marygail Brauner on avionics repair at NADEPs.

SUMMARY

At a 1989 conference of senior Naval logisticians and RAND researchers at the Naval Postgraduate School, Monterey, CA, all Navy participants agreed on one point: the Naval aviation depots (NADEPs) have a "materiel problem." More precisely, there was a consensus that repair processes at the NADEPs are often brought to a halt because needed repair parts are not immediately available. There was no consensus on the source(s) of the materiel problem, however, because materiel support in the Navy is the responsibility of several different functional organizations, each with its own perspective, concerns, and performance measures. A decision was made to investigate the materiel problem to see where its sources lay.

To this end, we conducted a case study involving the TF-30 jet engine (the power plant for the F-14), which is repaired at NADEP Norfolk. The TF-30 was chosen for several reasons: (1) the aircraft and engine are mature, having been in service since the early 1970s; (2) the engine is not currently in production, so depot repair is critical to keeping the engine operational in the field; (3) the parts demand data for the TF-30 are of good quality because parts requests are screened through a special information system—the NADEP Logistics Management System (NLMS); and (4) materiel problems are said to be an issue in TF-30 repair. Moreover, based on our ongoing research, we believe that the problems associated with TF-30 repair generalize to other major end items and all NADEPs.

Our study examined the materiel problem using three measures that correspond, respectively, to three perspectives on the supply system: (1) aggregate delivery times (perspective of depot artisans and the supply system); (2) demand-supply profiles (perspective of inventory control points [ICPs]); and (3) impact of parts delays on engine repair (perspective of depot management).

DATA USED

We used data from the Naval Industrial Materiel Management System (NIMMS) and procurement data. NIMMS logs every materiel transaction made by artisans and by depot parts stores. The transactions are primarily parts issues and requisitions; however, such actions as turn-ins of unused materiel and cannibalization of parts from other engines in repair are also logged. For this study, we used transactions from January 1989 to January 1991.

The procurement data were acquired from the three ICPs that manage the vast majority of parts used on the TF-30: the Navy's Aviation Supply Office (ASO), the Air Force's Oklahoma City Air Logistics Center (OCALC), and the Defense Logistics Agency's Defense Industrial Supply Center (DISC). Additional procurement data came from the Norfolk Naval Supply Center (NSC), which does local procurement for NADEP Norfolk for some selected parts.

EXAMINATION OF THE PROBLEM

The objective of the study was to use the NIMMS and procurement data to look at the materiel problem from each of the three perspectives and to determine the causes of that problem. In particular, we hoped to gain insight into the direct role that procurement plays in solving acute shortages of parts.

Before examining the materiel problem from the three perspectives, however, we analyzed the NIMMS data to see whether the claims of a materiel problem were indeed justified. The analysis revealed that for the 451 engine repair jobs in the data set, the median total time required to deliver all needed parts was 102 days. Since repair time for an engine when all parts are available is only a few weeks, there did appear to be a real delay in the engine repair process when parts were not immediately available—one that could be examined from the three perspectives.

Perspective 1: Analysis of Aggregate Delivery Times

To analyze the materiel problem from the first perspective, we examined the delivery time for all parts requests in our data that were not satisfied by immediate issue from the depot's Navy Industrial Fund (NIF) store. The requisitions were divided into two categories: resolved (terminated with an issue in the NIMMS data) and unresolved (not terminated with an issue), and within those two categories they were grouped by requisition priority. Delivery times were then compared to the Uniform Materiel Movement and Issue Priority System (UMMIPS) standards. For resolved requisitions in priority group 2 (the majority of the requisitions), 40 to 50 percent of the deliveries did not meet the UMMIPS standard of 12 days. While there were some differences in delivery performance for parts managed by the three most important ICPs, the overall pattern of performance was similar for all three groups. In addition, high-priority items were not delivered more rapidly than items of lower priority.

Unfortunately, these results were all we could learn from this analysis: aggregate delivery times do not reveal whether specific parts are responsible for most

of the observed delays, nor do they allow us to determine what causes the delays. To answer these questions requires a more detailed look at the demands and issues for individual parts, as well as an examination of the actions taken by other segments of the supply system.

Perspective 2: Analysis of Demand-Supply Profiles

To analyze the demands and issues for individual parts and the associated actions by the other segments of the supply system, we had to bring together information from NIMMS on artisan parts requests and issues, stock replenishment information from the NIF store, and information on procurement actions undertaken both locally at the Norfolk NSC and at the ICP responsible for the part. To provide a concise assemblage of this information, we introduced the demand-supply profile, which summarizes the data in graphic form. Parts were ranked according to the total number of days their unavailability kept an engine repair job waiting. Demand-supply profiles were then plotted for the top ten problem parts for each cognizance code associated with the ICPs.¹

For reparables managed by ASO (cognizance code 7R), we found two patterns. The first, which held for most of these parts, was that they were in fairly steady demand and apparently in stock at the local NSC² but took several days to be issued. The second pattern, which held for two of the top ten parts, was that demand was very limited and ICP intervention appeared to be necessary to get parts because they were issued only after ASO had received a shipment of them.

Consumables managed by ASO (1R), parts managed by DISC (9Z) and OCALC (9J), and parts manufactured locally had a different pattern: periods in which the part was in stock at the NIF store alternated with fairly lengthy periods during which the part was out of stock. When a part was out of stock, 20 to 40 days elapsed before the item was received by the NIF store and the backordered requests filled.

Overall, it was striking that relatively few of the delays seemed to result from difficulties in procuring the part at the ICP level. Requests were eventually filled after only moderate periods of time and were not correlated with receipts or procurement actions at the ICPs.

¹Cognizance codes were used (instead of ICPs) as identifiers because ASO has a separate cognizance code for its two kinds of parts: one for *reparables*, which can be repaired at a depot or by a contractor, and one for *consumables*, which are discarded when broken.

²Navy policy is that reparables are not stocked at the NADEPs.

Perspective 3: Analysis of Impact on Repair Time

From the Navy's point of view, two measures are relevant indicators of the impact of the materiel problem. The first measure is the engine days of delay (i.e., the total number of days an engine repair job is delayed because needed parts are unavailable). The second measure is the number of engine jobs for which a part is required and is a problem (i.e., is not immediately available).

The lists of the ICPs' top ten problem parts serve for the first measure. A rough approximation for the second measure can be obtained by looking at the number of jobs in which a specific part caused the maximum delay. In our data, 6 parts from the four top-ten lists used in the demand-supply profile analysis caused the maximum delay for 25 percent of the engine jobs. Fifty-six parts (out of the over 2000 ordered in our data) caused the maximum delay for 66 percent (300 of 451) of the engine jobs. Engine days of delay therefore seem to be a good indicator of a problem part. However, the maximum delay for the final 34 percent (151) of the engine jobs resulted from the unavailability of 125 different items.

CONCLUSIONS

We reached three major conclusions. First, engine days of delay are a good indicator of which parts are the primary causes of the materiel problem. Second, of the maximum delays for engine jobs, 66 percent are caused by a small subset of parts (56 out of over 2000 ordered in our data), whereas the remaining 34 percent are caused by a very heterogeneous set of parts that are only rarely a problem. Third, the materiel problem has two causes. Most of the delays seem to arise in getting parts to the depot from other segments of the DoD supply system—not from problems in acquiring the parts at the ICP level. However, about a fifth of the problem parts in the top-ten lists seem to be experiencing delays that originate outside the DoD supply system. Stockouts of these parts were resolved by procurement actions. All of these delays cause a lack of continuity in depot work and clog depots with excess in-process jobs.

RECOMMENDATIONS

Our conclusions led to four recommendations, the last two of which describe ways to implement the first two.

- 1. The Navy needs to reduce the delay involved in getting parts to the depot when those parts are in stock in the Navy or DoD supply system.** The focus here should be on the parts that have the most impact on total engine days of

delay. These parts appear to be in the DoD supply system but take a significant amount of time to get to the depot when requested. The key step is to assess the length of time taken by the various parts of the supply pipeline so that sources of delay can be pinpointed. This information will determine what has to be done to solve the problems: better visibility, faster transportation, streamlined administrative procedures, etc. We already know that the shipment of ASO-managed reparable between the local NSC and the depot is a source of delay. Thus, since these parts appear to be in fairly heavy demand, stocking them at the depot could eliminate several days of delay per request. Different methods of planning and of ordering parts in anticipation of use could also help to improve the number of parts requests satisfied at the depot.

2. The Navy needs to address delays at the ICP level. The demands for seven of the parts in the four top-ten lists were met by actions above the depot—i.e., issues were tied to the receipt of shipments of these parts by the responsible ICP or by local procurement. There thus seems to be a clear role for the improvement of the procurement process as well, especially the ordering and receipt of parts that are holding up repair.

3. The quality of the NIMMS data needs to be upgraded to make the data more useful for analysis. Our analysis shows that the NIMMS data can be effectively used to find out which parts are problems in engine repair. However, the NIMMS data have some quality problems that can affect the Navy's ability to perform similar analyses as an ongoing monitor of the materiel problem. Most important is the question of unresolved requisitions (i.e., those lacking explicit terminating transactions) for parts not in stock. In some cases, a requisition can be determined to be satisfied from other evidence, but the lack of an exact termination date makes it necessary to estimate the delay involved, and that estimation can skew delay times in either direction. These and other technical problems need to be addressed in NIMMS and in any future depot information systems.

4. The Navy needs to be able to integrate several diverse information sources if it is to analyze the materiel problem. A comprehensive diagnosis of the materiel problem requires the integration of information from the NADEP, the local NSC, and the ICP responsible for each part. For our study, this meant that data had to be extracted from several different data systems, a time-consuming and imperfect process. This type of information needs to be available on a regular basis and should be augmented with other, currently unavailable information, such as

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historical positions of ICP-managed stocks. This type of data integration is crucial to any attempt to solve the materiel problem. Since the number of parts found to be causing a large majority of the delays was small, the data interchange requirements should be fairly minimal.

ACKNOWLEDGMENTS

This study is indebted to many people who provided insight and advice at crucial junctures. RAND colleagues from the Navy project deserve special mention. James Hodges and Judith Payne were responsible for formulating the "materiel problem" part of the project and for doing the original work on the TF-30 case study. Marygail Brauner, Daniel Relles, and James Hodges read and commented on early drafts of this Note. Jack Abell helped to guide the learning about logistics and the Navy.

RAND colleagues John Folkeson and John Dumond commented on some of the results, particularly the demand-supply profiles. Paul Steinberg's comments greatly improved the presentation. The comments of Ken Girardini, who reviewed the Note, improved many parts of the document, particularly the formulation and statement of the conclusions and recommendations. Finally, Jeri O'Donnell did an expert job of editing.

The Navy personnel who aided this research included CDR Barbara Riester, Zane Ward, and Peggy Couch of NADEP Norfolk, and Jackie Attaway of NADEP Cherry Point, who explained how the depot uses NIMMS data. We received much valuable information from Nancy Powers, Reid Peschell, and Bev Thomas of the ASO in Philadelphia. Our NIMMS data were extracted by Rich Riley of NADEP Norfolk. Julie Cuorato and Alicia Ingber assisted us at DISC, and further insight into NADEP and NSC operations was provided by CAPT Charles Sapp and LCDR Nick Zimmon of NADEP North Island. Finally, we would like to thank ADM James Eckelberger, commander of ASO up to fall 1991, and RADM Donald Eaton, commander of AIR-43, for their interest and encouragement.

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GLOSSARY

ALC	Air Logistics Center
APADE	Automated Procurement and Accounting Data Entry
ASO	Aviation Supply Office
DISC	Defense Industrial Supply Center
DLA	Defense Logistics Agency
DoD	Department of Defense
FAD	force activity designator
GSA	General Services Administration
ICP	inventory control point
IPG	issue priority group
MILSTAMP	Military Standard Transportation and Movement Procedures
NADEP	Naval Aviation Depot
NAVAIR	Naval Air Systems Command
NIF	Naval Industrial Fund
NIIN	National Item Inventory Number
NIMMS	Naval Industrial Materiel Management System
NLMS	NADEP Logistics Management System
NSC	Naval Supply Center
OCALC	Oklahoma City Air Logistics Center
RFI	ready for issue
TP	transportation priority
UMMIPS	Uniform Materiel Movement and Issue Priority System
UND	urgency of need designator

1. INTRODUCTION

BACKGROUND

At a 1989 conference of senior Naval logisticians and RAND researchers at the Naval Postgraduate School, Monterey, CA, all of the Navy participants agreed on one point: the Naval aviation depots (NADEPs) have a "materiel problem." More precisely, there was a consensus that repair processes at the NADEPs are often brought to a halt because needed repair parts are not immediately available. However, there was no consensus on the problem's dimensions, exact characteristics, and causes. Is there one set of problem parts, or does the problem involve most of the parts needed for repair? Are problem parts in stock in the DoD supply system, or are they unavailable because of procurement problems?

How one goes about finding the answers depends on where one sits in the Navy's supply and maintenance systems. Materiel support in the Navy is the joint responsibility of several different functional organizations, each with its own concerns and performance measures and thus its own way of looking at the problem. While each of these perspectives provides insight into the problem, the divergence of viewpoints means that attempts to explore both the sources of materiel problems and their solutions tend to be politically contentious.

There are three main perspectives. The first—associated with depot artisans and the Naval supply system—is concerned with aggregate delivery time: the average time it takes to satisfy any requisition for repair parts. To the artisan, materiel support is adequate when the parts needed to finish a particular job are available with minimum delay. Delays of more than a few hours mean that work must be put aside and that several repair jobs must be in progress at the same time in most shops to keep the artisans busy. As for the supply system, it is even more directly interested in the time taken to satisfy requisitions—delivery time is the primary measure of its performance.¹ The drawback with

¹The DoD promulgates the Uniform Materiel Movement and Issue Priority System (UMMIPS) in DoD Directive 4410.6. These standards specify how long a requisitioned part that the logistics system has in stock can take to be delivered for different requisition priorities and various destinations. DoD also publishes reports that rate the performance of each of the services.

looking solely at aggregate delivery times, however, is that one gains no insight into the problems posed by particular items.

The second perspective focuses on individual items and devises particular solutions for their particular problems. This perspective is roughly that of the inventory control points (ICPs). They manage by item based on usage—i.e., the demands on the supply system for each item.² But this perspective does not account for the fact that all items do not have the same impact on the time the depot takes to finish a repair job.

The third perspective—impact on repair time—focuses on the time an item spends in the repair process and tries to identify the “pacing” parts (i.e., the problem parts causing most of the delay for that specific repair job). Those parts then determine which actions will be most effective in speeding up the delivery of needed parts to repair organizations. This view is the depot management’s perspective, since the depot is paid by the number of completed repairs it produces. It is also the perspective of Naval Air Systems Command (NAVAIR), because engines undergoing work in the depot cannot be installed in aircraft or serve as spares in the fleet. The longer the repair time, the greater the number of items that must be procured to cover the repair pipeline.

The functional organizations are aware of their three different ways of viewing the materiel problem. However, each organization keeps its own perspective paramount, since that perspective is usually the basis for judgments about the organization’s performance. The problem is that the different perspectives entail performance goals that are in a real sense incommensurable and that can lead to degraded performance for other organizations.³

OBJECTIVE

Based on the contention that, from the point of view of the Navy, the measure of a *problem part* should be its impact on the time needed to repair an item in the depot and that the measure of the supply and maintenance systems’ performance is the depot’s ability to repair end items as quickly as possible, we

²The ICPs do not see direct demands by artisans as our case study did (see Section 4). According to unpublished work by J. S. Hodges, the effect is distortion in the ICP item management decision processes. Artisan demands end up being “hidden” for several quarters because they are filled from lower-level stocks.

³For example, suppose the depot has ten engines under repair, each needing the same ten parts. If the supply system can supply ten each of nine parts, it has a 90 percent success rate. However, the depot still cannot finish even one engine!

examined the materiel problem from the three perspectives described above. Specifically, we started with a straightforward examination of delivery times; looked at demands, issues, and procurement actions for problem parts; and then analyzed the impact of parts on the repair process in a case study of materiel support for the repair of a single end item—the TF-30 jet engine. By focusing on the parts demanded and supplied for a single end item, we were able to examine supply performance and quantify its effect on repair turnaround times.

The TF-30 engine, which is repaired at NADEP Norfolk, is the power plant for the F-14A Tomcat, the current air-superiority fighter for the U.S. Navy. This engine was selected for our study because (1) the F-14A and all its equipment are mature (allowing us to avoid the transient materiel support problems that often surface when an item is undergoing initial fielding); (2) depot repair will play a vital role in keeping the F-14A operational, as planned, into the twenty-first century (since neither the F-14A nor the TF-30 is currently in production); (3) the Naval Industrial Materiel Management System (NIMMS) data for TF-30 repair are screened by the NADEP Logistics Management System (NLMS) to validate repair parts requests for an item against a bill of materials for the TF-30; and (4) repair parts are an important constraint for TF-30 repair, which requires parts from several different DoD ICPs. In addition, we believe that materiel support for the TF-30 does not significantly differ from materiel support for other Navy engines and weapon systems and thus can serve to represent the issues involved in the materiel problem.

DATA USED

Two types of data were used for this study: transactions extracted from NIMMS, and procurement data from the ICPs that supply the majority of parts for the TF-30. In discussing the data, we refer to details of the depot repair process for the TF-30 engine, a background description of which is provided in the Appendix.

NIMMS Data

To examine materiel supply performance for depot repair of the TF-30, we turned to NIMMS, which (among other functions) logs every materiel transaction made by NADEP artisans and by the NADEP's supply organizations (such as the Naval Industrial Fund [NIF] store). Each NADEP keeps its own NIMMS data locally. The transactions are primarily parts requisitions and issues (one specific

type of part per transaction, although the quantity may vary), but NIMMS also logs other materiel actions, such as turn-ins of unused material and cannibalization of parts from other repair jobs.

A request for an item that is in stock in the NIF store is recorded in NIMMS as a single transaction, an issue. A request for an item that is out of stock at the NIF store causes a backorder transaction to be entered, signifying an unsatisfied demand; a request for an item not stocked at the NIF causes a requisition transaction to be entered, also signifying an unsatisfied demand. When the backordered/requisitioned item arrives at the depot and is issued to the artisan, an issue transaction is entered—bearing the original requisition date and number—to close out the request as satisfied. Since each transaction also includes the job number and the transaction date, it is possible to build up a log, by engine job, of which parts were requested and how long the supply system took to provide them.

As noted above, at NADEP Norfolk the NIMMS transactions for TF-30 repair are screened by NLMS, an information system that has been in development at NADEP Norfolk since the early 1980s. Most important for our work is the fact that NLMS checks all parts requests against an end item's bill of materials,⁴ whereas NIMMS alone simply tracks parts requests and issues, not verifying whether parts requested on a job are actually for the engine being repaired. This nonverification has reportedly allowed some abuses, i.e., artisans sometimes cross-order needed pieces to build up a bench stock of parts in anticipation of a supply failure. However understandable the reasons behind these practices, their existence severely constrains the use of unscreened NIMMS data to study the impact of supply performance on the repair of a particular item.

In early 1991, we asked the data shop at NADEP Norfolk to send us the NIMMS transactions for all engine jobs and component repairs for the preceding two years. We received a file containing transactions dated January 20, 1989, to

⁴Some of NLMS's other functions are to automatically build and maintain bills of materials, keep electronic logs of repairs on individual engines, and keep track of engineering modifications. Development of the parts request validation function began in 1988, and the first end item to come under NLMS was the TF-30. ABOM (Automated Bill of Materials), another system in use in various forms at other NADEPs, shares some functionality with NLMS.

January 23, 1991,⁵ from which we extracted the transactions pertaining to TF-30 engine repairs.

Within our two-year window of data were transactions corresponding to 475 different engine jobs.⁶ Eight jobs were eliminated because they had no parts requisition or issue transactions. Of the remaining 467 jobs, 16 consisted of transaction sets for which there were no initiating requisitions (i.e., the sets consisted solely of issues or modifications to requisitions),⁷ which means that no parts were ordered for these jobs within our window. We eliminated these 16 as well and, in general, restricted our analysis to the transactions for the remaining 451 engine jobs.

Because some requisitions are not satisfied by a single issue, we chose to use the term *requisition* somewhat loosely to mean a request-issue pair. If a requisition was satisfied by several issues, the original requisition was split into a set of requisitions, one per issue, all considered to have been submitted at the time of the original requisition. An unresolved requisition was generated for all requests not completely satisfied by an issue, either because the requisition had no recorded issue or the recorded issues did not add up to the quantity requested (in the latter case, the original requisition was split into one unresolved requisition and a set of resolved requisitions). Note that this approach gives the system credit for getting any portion of a requisition to the depot.

The 451 engine jobs entailed 28,130 actual requisitions, from which 28,198 request-issue pairs were constructed.⁸ Of these, 139 originated before 1989. We eliminated these 139 because we had some evidence that these requisitions were

⁵This time period includes Operation Desert Shield and the very beginning of Operation Desert Storm; however, the TF-30 was not one of the Navy jet engines whose repair was surged. Operation Desert Shield/Storm had surprisingly little effect on the materiel problems affecting the TF-30 in our data.

⁶In the two years previous to our window, most TF-30s had undergone a major engineering modification (according to Zane Ward, NADEP Norfolk). Virtually all of the engine repair in our data thus consists of minor repairs and foreign object damage, not major engine overhaul.

⁷The identification number for a set of transactions indicates the date of the original requisition.

⁸Clearly, the vast majority of transactions were very simple, having only a single requisition and a single issue. Note, however, that even though only one kind of part can be requested on a requisition, the quantity asked for can be greater than one. In our data, 65 percent of the request-issue pairs were for a quantity of one, and 90 percent were for ten or fewer.

abnormal, which left us with a final total of 28,059 "requisitions" for 2109 different items.⁹

The TF-30 requires not only items managed by the Navy, but items managed by the Air Force and the Defense Logistics Agency (DLA) as well. Moreover, the number of items supplied by non-Navy ICPs is not trivial: Table 1.1 shows the breakdown of TF-30 items by responsible ICPs.

Table 1.1
Number of Items and Requisitions by ICP

ICP (Cognizance Code)	Requisitions	Items
ASO (1R)	8,431	432
ASO (7R)	1,377	42
DISC (9Z)	8,130	791
OALC (9J)	8,638	619
Other	1,483	225
Total	28,059	2,109

The ICPs responsible for the procurement of specific items are identified in NIMMS (and other Navy materiel information systems) by *cognizance codes* (or symbols). The Aviation Supply Office (ASO) has two cognizance codes: 1R for *consumables* (parts discarded when broken) and 7R for *reparables* (items that can be repaired at a depot or by a contractor). The cognizance code for parts managed by the Oklahoma City Air Logistics Center (OALC), an Air Force ICP, is 9J; the code for DLA's Defense Industrial Supply Center (DISC) is 9Z. The "other" category subsumes twelve cognizance codes for several other Air Force Air Logistics Centers (ALCs), another DLA ICP, and the General Services Administration (GSA).

A preliminary examination of the data revealed that even with NLMS acting as a front end to NIMMS, there were a number of anomalies. The most serious were sets of transactions that were not closed with an issue. For some of these, there was a partial issue; for others, no issue at all. Also, some cases were apparently closed by submitting a requisition with a zero quantity or by entering an increment/decrement transaction that reduced the outstanding quantity to zero. A further complicating factor was that this implicit closure often occurred

⁹This elimination of requisitions initiated before January 1989 could bias estimates of delivery time downward. However, the number eliminated is trivial, and many of these requisitions were unresolved even though the same parts were issued on other jobs in 1989, indicating that the unresolved status may well have been an error.

long after the part requested was issued to another job, indicating that the part was at least available in some quantity. And there were sets of transactions containing increment transactions or additional requisitions for the originally requested quantity that were resolved by an issue for the original quantity. In these cases, the anomalous records seemed to be "reminders" to the supply system that the part was still needed.

While these anomalies constituted but a small proportion (1000) of the 28,059 requisitions, the parts involved were precisely those that the supply system was having trouble providing. We devoted significant effort to understanding the various problems and to cleaning up the data base using various sets of rules to detect different problems and construct corrected request-issue pairs.

Procurement Data

Once problem parts were identified from the NIMMS data, we wanted to examine contemporaneous information from the ICPs to see whether item-specific problems were being caused by low levels of stock at the wholesale level. This task was extremely difficult. ICPs in the various services use different information systems, and most do not keep historical information on their stock positions. However, all ICPs keep information on contract actions (so that their procurement staffs can compare prices, lead times, etc.). Therefore, it was possible to determine whether an issue to the depot was correlated with procurement actions such as contract awards. Here, too, ICP diversity caused problems: certain ICPs record only contract award dates, whereas others record the receipt date of shipments. We used some of these sources, particularly for our analysis of demand-supply profiles (see Section 4).

The NSC does some local procurement in support of the NADEP. Some items are always bought locally; others, commonly provided through the supply system, are occasionally procured locally if there is an urgent need. The depot maintains purchase history information in APADE (Automated Procurement and Accounting Data Entry), including purchase dates. These dates roughly flag times at which the materiel supply situation at the depot required action by the local procurement people.

Somewhat more detailed information on procurement actions is available from ASO. In addition to recording purchase dates, the ASO Contract Data File records dates when shipments were made and received. A procurement history

data file is also managed by OCALC.¹⁰ This file's information is closer to that of APADE—contract award dates and first delivery dates. There is no indication, however, of whether the recorded delivery dates are the scheduled ones or the actual ones. Nor is there mention of how multiple deliveries are indicated (if indeed they are).

DISC, too, maintains a procurement data base, but it is both more extensive and differently organized than the ASO and OCALC data bases. We were unable to acquire a machine-readable data set for the parts we were investigating, so we requested a set of paper reports on a limited set of parts. The three reports used in this study were the Contract History File Interrogation, the Special Supply Control File Printout, and the Contract Technical Data File Interrogation Reply. They contain the contract award dates for each buy and ship dates for each shipment.

DOCUMENT OUTLINE

Section 2 briefly describes how we used the NIMMS data to substantiate the claim that there is indeed a materiel problem. Sections 3, 4, and 5 then use the NIMMS and procurement data to look, respectively, at the materiel problem from each of the three perspectives—i.e., in terms of aggregate delivery times, demand-supply profiles, and overall impact on engine repair time. Section 6 summarizes the findings of the case study and makes recommendations.

An appendix is also included. Its purpose is to provide background information for those readers unfamiliar with the depot repair process and the materiel supply processes that support the NADEP.

¹⁰The Air Force designation for the history tape is J041 BZM6X1.

2. SUBSTANTIATION OF MATERIEL PROBLEM

Before analyzing the materiel problem from each of the three perspectives, we used the TF-30 NIMMS data to substantiate the claim that there is a materiel problem—i.e., that engine repair jobs do suffer from delays caused by unavailable parts.

Table 2.1 shows TF-30 engine repair jobs broken down by the quarter of their first transaction in our NIMMS data set. It gives a rough idea of the time flow of jobs into the depot.¹ As can be seen, the number of job starts can fluctuate substantially. (Some of this fluctuation results from the depot having a certain amount of latitude in how it manages the flow based on available funds, engine carcasses, and the status of engines currently in work.)

Table 2.1
Engine Job Starts (First Transaction) by Quarter

Quarter	CY 89	CY 90
Jan-Mar	59	49
Apr-Jun	47	37
Jul-Sep	40	42
Oct-Dec	55	35

We can get some information about the effect of materiel support on engine repair by plotting the number of parts per TF-30 job versus the total length of the job (defined here as the number of days between the date of the last and first NIMMS transaction for a particular engine job), as we have done in Figure 2.1. The actual time for the depot to complete an engine job can be either more or less than this amount. If all parts needed for a job are acquired but a great deal of labor remains to be done, this measure will understate the length of the job. Conversely, if needed parts are cannibalized from other engines awaiting repair, some engines may be completed before their requisitioned parts arrive (those parts are then used on the

¹This approach does have the potential to introduce some bias in job starts for the first quarter of CY 89. If a particular job began before our data window but all of its materiel transactions from before January 1989 had been completed, we counted that job as starting at the date of its first transaction in our data set, e.g., the first one in or after January 1989. Note that 87 of the 451 jobs in our data began before the first quarter of CY 89, i.e., they had outstanding requisitions in our data from before January 1989.

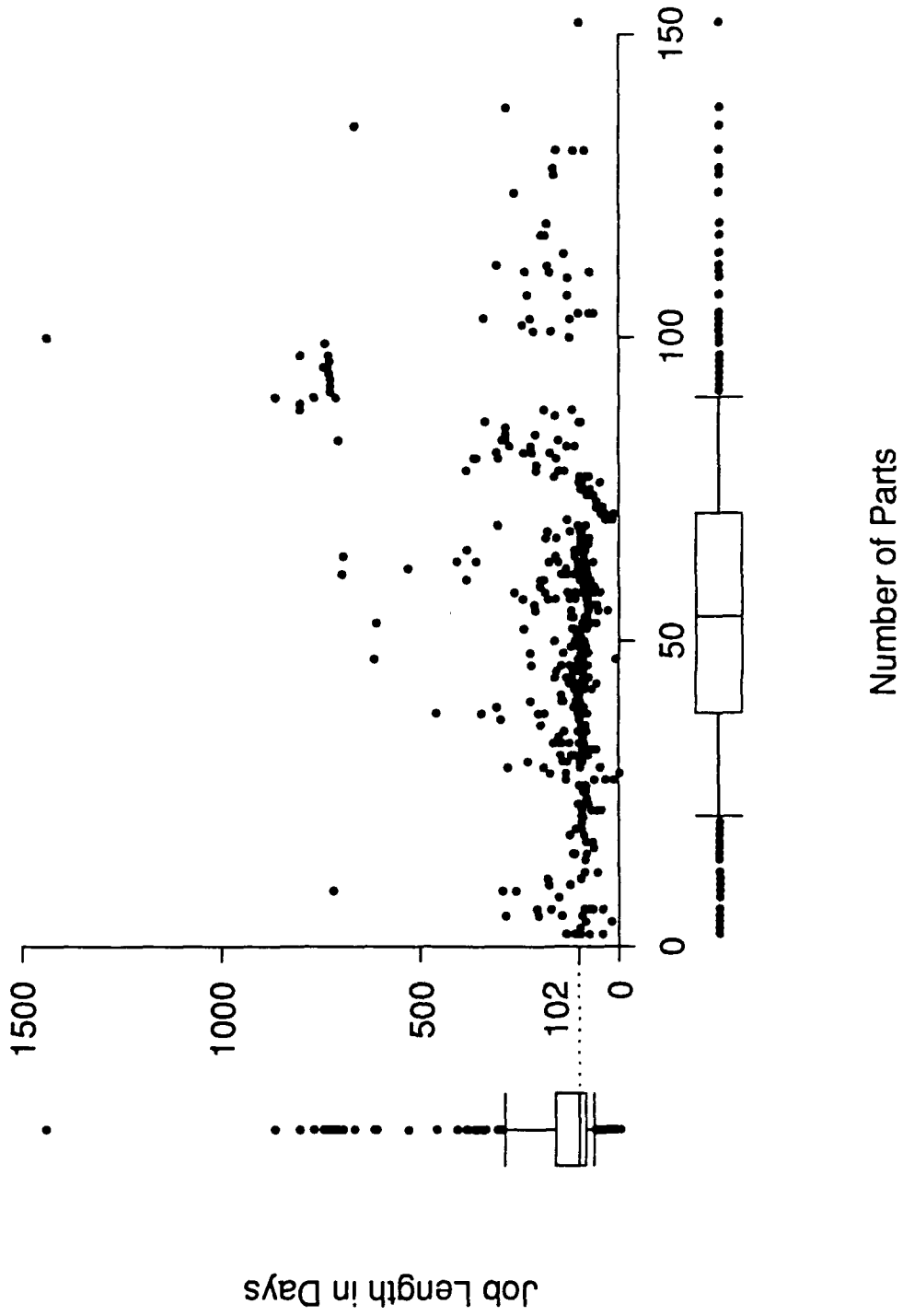


Figure 2.1—Length of Job Versus Number of Parts Used for TF-30 Engine Jobs (1989-1991)

cannibalized engines). However, since our analysis focused on the impact of materiel support, defining the job length in this way is appropriate.

Figure 2.1 has two parts: (1) a central scatterplot in which each engine job is represented by a point whose horizontal and vertical coordinates give, respectively, the number of parts required and the job length (in days); and (2) two boxplots that give the univariate distribution of the quantities on the two axes. In each boxplot, the five parallel lines mark the 10th, 25th, 50th (median), 75th, and 90th percentiles for the data. Data values that lie beyond the 10th and 90th percentiles are individually plotted.

Notice that there is no strong relationship between the number of different parts required for a repair job and the length of the job (i.e., the total amount of time required to get the parts). Ninety percent of the jobs lie in a broad horizontal band with parts requirements ranging from only a few parts to over 100. The median time to complete an engine job was found to be 102 days (i.e., 50 percent of the jobs took longer). When all parts are available and there is enough manpower, the usual repair time is on the order of two to three weeks. Thus, the fact that 98 percent of the engine jobs took longer than this amount of time to complete indicates that there is a source of delay in engine repair.

3. ANALYSIS OF AGGREGATE DELIVERY TIMES

From one perspective, the materiel problem is seen in terms of the time it takes to satisfy a request for repair parts. This is the view of the depot artisan, whose ideal is to have each demand for a part satisfied immediately. A delay means loss of efficiency, since work must be put aside until a missing part arrives. If there are many delays, artisans must keep several repair jobs going simultaneously if they are to use their shop time well. This work-in-progress can clutter shop space and impede repairs.

For items in stock within the DoD, the supply system shares the artisan's perspective, and with good reason: supply system performance is graded on the basis of how long a part takes to get from storage to the requester. The DoD UMMIPS standards set limits for these times based on the priority of the requisition, and DoD publishes periodic reports grading the services and the nonmilitary supply agencies.

When we looked at the NIMMS data from this perspective, we found that there were indeed problems in getting requisitioned repair parts to the artisans.

DESCRIPTION OF ANALYSIS

As stated earlier, in Section 1, the 451 engine jobs active in our two-year data window (January 1989 to January 1991) had a total of 28,059 requisitions. Table 3.1 breaks down these requisitions by source of part. (See the Appendix for more details on sources of issue and the repair process in general.)

The measure of interest in this analysis is the time between the request for a specific item (quantity of one or more) and the issue of that item to the artisan. As the table shows, 63 percent of all parts needed for repair were in stock at the depot in

Table 3.1
Requisitions by Source of Issue

Source	Number of Requisitions
NIF store	17,681
Off-station	
Resolved	9,290
Unresolved	1,088
Total	28,059

the NIF store,¹ and the requests for the remaining 37 percent of the parts went *off-station*, i.e., were satisfied by issues from the local NSC or from other parts of the Navy or DoD supply system. For items in stock at the depot (in the NIF store), the time between request and issue is zero; our focus was on requisitions that had to go off-station. Note that off-station requisitions are for two types of items: those the NIF store normally does not stock and those the NIF store stocks but is out of at the time of the request.

The time that elapses in filling the off-station requisitions should be a simple quantity to derive from the requisition and issue transactions. There are, however, two complications, the first being that not all requisitions lead to a single issue. Sometimes the quantity requested arrives in several shipments; sometimes only a portion of the shipment is received.

The second complication concerns unresolved requisitions. We can infer that some of these have been satisfied by the fact that there is a final requisition for a quantity of zero or an increment/decrement transaction that reduces the outstanding quantity to zero. However, other transactions provide no such indication. We imputed a termination date for these types of unresolved requisitions as the earlier of the following: the date of the next issue of the same part to another job (subsequent to the date of the unresolved requisition) and the date of the last transaction for the job. If the unresolved requisition was the last transaction, the end of the data set was taken as the issue date. Note that this definition probably underestimates the actual time it took to receive the parts requested on the unresolved requisitions. In the absence of other information, however, this approach seems to be reasonable.

It would be misleading to compare the requisitions directly, since they are assigned different priorities that indicate to the DoD supply system how urgent they are and how quickly they should be satisfied. The priority scheme and the allowable UMMIPS delivery times are set in the Military Standard Transportation and Movement Procedures (MILSTAMP) documents.² DoD priorities are based on the force activity designator (FAD) of the requesting organization and the urgency of need designator (UND) for the particular item.³

¹By Navy policy, the NIF store does not stock reparable, so its fill rate (percentage of requisitions satisfied by on-hand stock) for parts that it is authorized to stock is somewhat higher than 63 percent. See the Appendix for more information.

²DoD 4500.32-R, Vol. I, March 1987.

³A unit's FAD indicates its military importance, ranging from FAD 1 (most important) to FAD 5. The UND has three levels: A—an item without which a requisitioner is unable to

FADs and UNDs together define 15 possible priority levels, numbered from 1 to 15 in order of decreasing importance. The depot has a FAD of 3, and most depot requisitions have priorities 3, 6, and 13, corresponding to the three possible UNDs.⁴ These UMMIPS priorities are then grouped into three issue priority groups (IPG-1, -2, and -3) and three analogous transportation priority groups (TP-1, -2, and -3) that determine the handling priorities at the depot and the time standards for delivery. The three depot priorities map into the three IPGs and TPs (priority 3 to TP-1, 6 to TP-2, and 13 to TP-3). For shipments within the continental U.S., the UMMIPS standards mandate delivery times of 8, 12, and 31 days for TP-1, -2, and -3, respectively. These times cover all activities from requisition submission to part issue.

RESULTS

One of the most persistent claims made about the materiel problem is that the parts causing the greatest delays are those managed by some particular ICP.⁵ Figures 3.1 and 3.2 show the distribution of delay times from requisition to issue for resolved and unresolved requisitions that went off-station. This distribution is broken down by both requisition priority and responsible ICP. The fraction of requisitions still unfilled is plotted for each of the three UMMIPS standard times (TP-1, -2, and -3). Ideally, 100 percent of the TP-1 requisitions would be satisfied in 12 days, 100 percent of the TP-2s would be satisfied in 8 days, and 100 percent of the TP-3s would be satisfied in 31 days.

Most of the requisitions in the NIMMS data were resolved (compare Figures 3.1 and 3.2). And, as Figure 3.1 shows, most of the requisitions fell into the TP-2 priority category (8631 out of 9290). Note also for this category that at 12 days (the UMMIPS standard delivery time for TP-2), 40 to 50 percent of the parts requisitioned had not been delivered to the depot. ASO's performance—both for consumables ("con") and reparable ("rep")—was precisely the same: 45 percent not delivered. Even at 31 days, there was a fair percentage still outstanding: 5 percent each of the

perform the assigned mission; B—an item without which a requisitioner would be impaired in performing the mission; and C—all other requisitions.

⁴Fifty-one of the off-station requisitions in our data had been assigned priority 20. This is not a valid UMMIPS priority, but it is the priority used in NIMMS for direct issues from the NIF. We assigned priority TP-3 to these 51 requisitions.

⁵Which ICP is thought to be at fault depends on the claim maker's position within the Navy supply system or the NADEP.

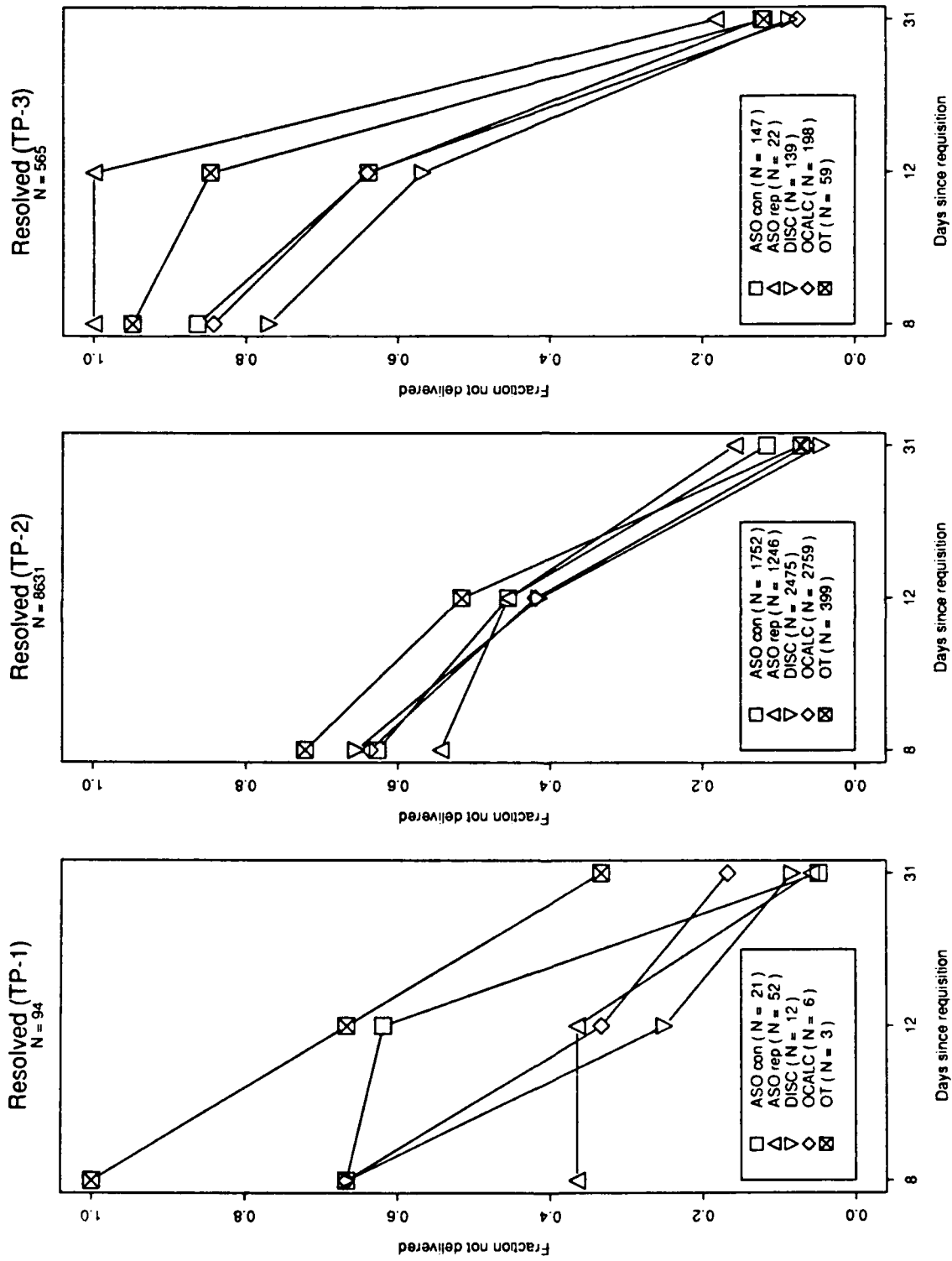


Figure 3.1—Time to Delivery for Resolved Requisitions

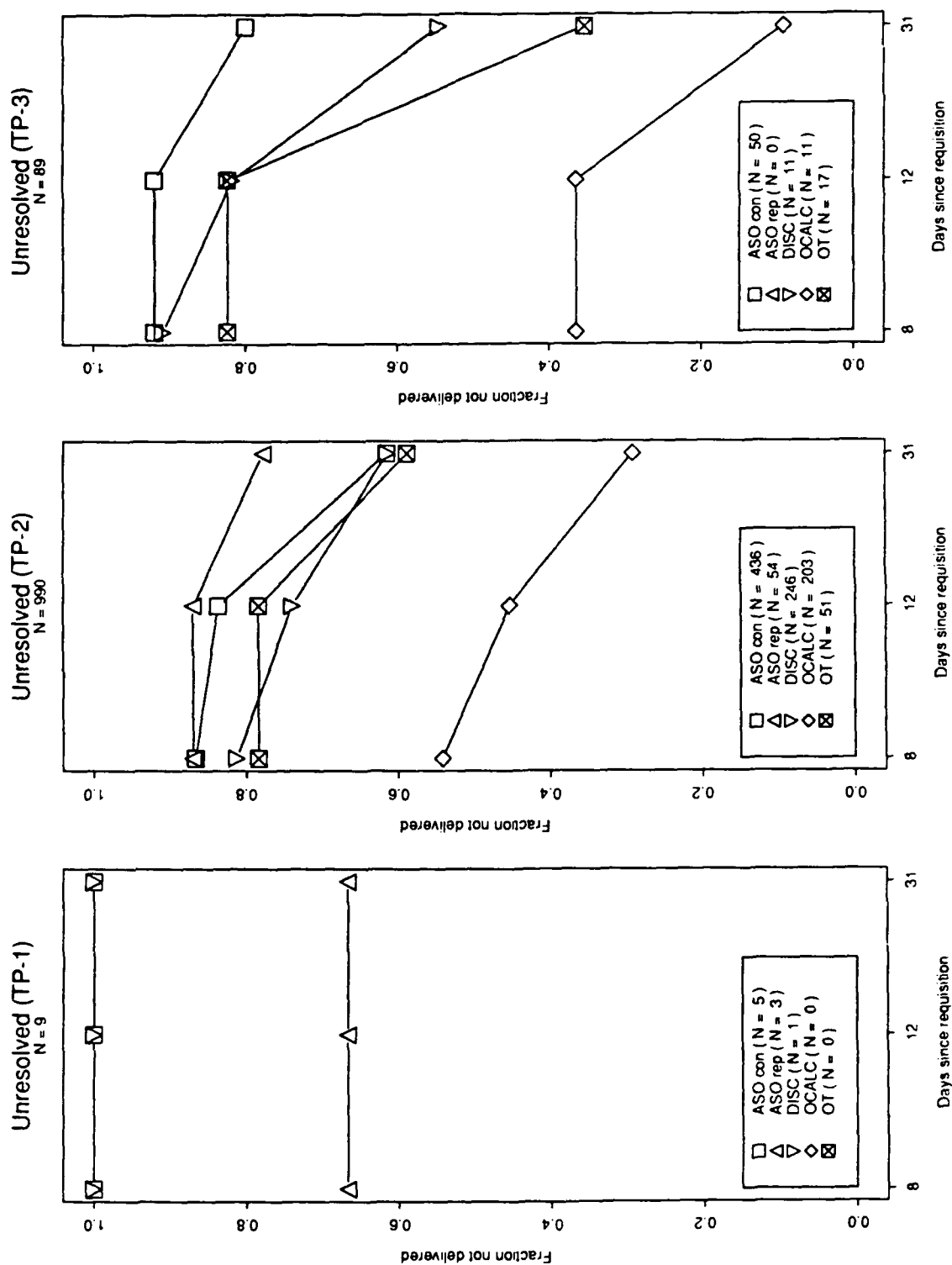


Figure 3.2—Time to Delivery for Unresolved Requisitions

parts managed by DISC, OCALC, and the other ICPs ("OT"); and 11 percent and 15 percent of the consumables and reparables, respectively, managed by ASO.⁶

The other two priority categories showed similar results for resolved requisitions. A high priority assignment did not seem to improve delivery in relation to the standard, although for DISC and OCALC parts the performance at 12 days is substantially better for TP-1 than for TP-2. As for the unresolved requisitions (Figure 3.2), their imputed part delivery times were much worse than the delivery times for the resolved requisitions, except in the case of parts managed by OCALC.

CONCLUSIONS

Our results are qualitatively the same as those reached by Hodges and Payne using a somewhat more limited set of data.⁷ As they observed, requested parts not in the NIF store take a substantial amount of time to be delivered (more than set forth in the UMMIPS standards). There are, however, two drawbacks to seeing the materiel problem solely in terms of aggregate delivery times.

First, focusing just on the delay does not allow the two possible sources of delay to be distinguished from each other. That is, the NIMMS data do not allow us to tell whether a part was in the supply system and simply took a long time to ship to the depot or had to be acquired by the responsible ICP. However, given the length of time required by the procurement process for most parts (a month to more than a year), we can infer that most of the parts issued within 31 days were almost certainly already in the supply system.

The second drawback is that the measures in this analysis do not directly map into delays in engine repair time. Although it is reasonable to infer that repair is being severely affected because approximately 4000 requisitions in the TP-2 category took more than 12 days to be satisfied, that fact is not as direct a measure of the impact of delivery delays as are the measures used in the following two analyses.

⁶These relatively greater percentages do not necessarily mean that ASO does a poorer job supplying materiel. The parts managed by ASO may be harder to stock and thus harder to supply.

⁷Hodges and Payne, unpublished research.

4. ANALYSIS OF DEMAND-SUPPLY PROFILES

After examining the aggregate times to receive parts from off-station to fill requisitions made by depot artisans, we concluded that a substantial percentage of these requisitions were taking a long time to satisfy, exceeding even the rather generous UMMIPS standards. We then turned our attention to examining delays for individual parts in more detail. However, we were interested not only in how long items took to be received from off-station, but in the broader questions as well: Did the NIF store stock enough of frequently demanded items? Were some items not stocked at the NIF store (such as reparable) demanded frequently enough that stocking them in the depot should be considered?

We addressed these questions by looking at the NIMMS data in another way for requests satisfied immediately from the NIF store and requests going off-station. In addition, in this analysis we were able to link procurement data to the NIMMS data to provide a more complete picture of how the supply system reacts to demands from the depot for repair parts. The analysis consisted of plotting the time pattern of requisitions and issues for individual parts in what we call a *demand-supply profile*. In some ways, this focus on the demand pattern for individual parts corresponds to the ICP's perspective of the supply system, but the profiles contain additional information as well.

We begin here by defining the demand-supply profile with an example. Because the profile aggregates a large amount of information, it is a rather complex graphic. Still, it is valuable in providing a comprehensive view of the problems encountered in obtaining a particular repair part from outside the depot. Following the definition, we use the profile to look at the top ten problem parts for each of the three major ICPs (ASO, DISC, and OCALC). The resulting profiles show several different patterns, indicating that materiel problems have several different sources.

DESCRIPTION OF ANALYSIS

As noted earlier, the NIMMS data record the requisition and/or issue of each item requested by the depot artisans. These raw data can be used to construct a requisition-outcome pair for each parts request (here we include both immediate issues from the NIF store and requisitions that must go off-station to be satisfied). The three possible outcomes for each pair are (1) resolved (the requisition is satisfied

by an issue), (2) unresolved (no issue is recorded in the data), and (3) unresolved (no issue is recorded but the data indicate that the part is no longer needed). If all such pairs are collected for each item in the data base and then sorted by the date of request, the resulting list shows the item's demand and the outcome patterns. This demand-supply profile can be graphically plotted so that other information, such as procurement data and requisitions and receipts from the NIF store, can be overlaid.

Because the demand-supply profile is complex, we introduce it here in two steps. Figure 4.1 shows a section of the profile for one part used in the TF-30 engine, NIIN LLNA43331.¹ This section indicates the time pattern of artisan demands for this part and the time that elapses before issues are made.

The list on the left side of the plot identifies the NIIN for the part whose profile is plotted, the number of days engine jobs waited because the part was not available (i.e., the engine days of delay, or "Edays"), and the number of jobs for which the part was demanded. The dollar amount shown is the median of the standard unit prices recorded in all the NIMMS transactions in our data for the part.²

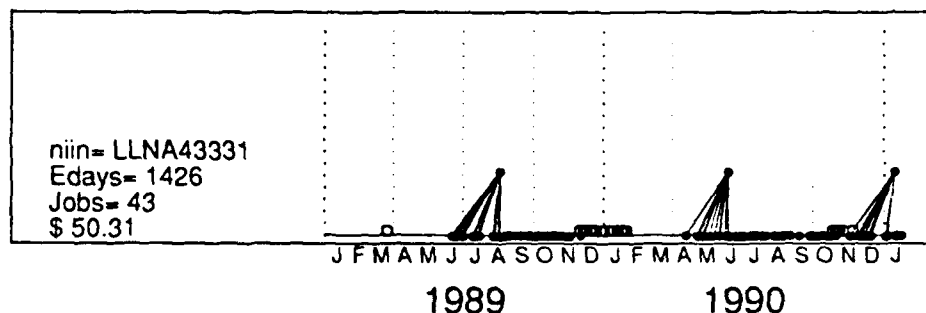


Figure 4.1—Partial Demand-Supply Profile (Requisitions and Issues Only)

¹NIIN (National Item Inventory Number) is a unique nine-digit code assigned to each item stocked by the U.S. government. Most NIINs are numeric; the "LL" in the NIIN for this part indicates that the part is locally manufactured, while the N indicates that it is stocked by the NIF store. Since it is locally manufactured, ASO does not procure the item, although the item is classed with the ASO-managed parts (cognizance code 1R).

²The NIMMS data record four prices for each part in each transaction, but only the standard unit price is nonzero for virtually all of the parts. The standard unit price does vary from transaction to transaction for a given part, but most of the differences are fairly modest. Using the median price gives some protection against being unduly affected by extreme values of the price, which could be caused by data entry errors (although some parts may have very inflated unit prices if acquired in small lots).

As noted in Section 1, we restricted the analysis to requests for parts that originated within our data window: January 1989 through January 1991. Requests for parts made to the NIF store (whether the part was issued or backordered) or to the Naval supply system are plotted as circles on the baseline at the date the request was entered into NIMMS. The filled circles indicate requests that were eventually satisfied with an issue that was recorded by NIMMS. If the issue was made by the NIF store on the same day as the request, the entire transaction is represented by one filled circle at the date of the request. If there was a delay in issuing the part, the issue date is represented by a filled circle above the baseline at the date of issue. The open circles on the baseline represent unresolved requests (those for which an issue was not recorded in the NIMMS data).

Figure 4.1 clearly shows the problems encountered with the part profiled. A steady demand for the part started near the middle of 1989 and was not met for about 2 months. After that time, there was enough stock at the NIF store to meet all demands until about the end of the year. The NIF store then apparently ran out of stock, and the next sequence of demands was never met. Demands stopped in the first part of 1990 but resumed later in the year, remaining unmet until almost the middle of the year. The item then remained in stock almost until the end of 1990, at which time the pattern of unmet demands and deferred demands repeated. The item was back in stock in the NIF store at the beginning of 1991.

The second section of the demand-supply profile adds information about the activities of the NIF store, local procurement, and ICP procurement. Figure 4.2

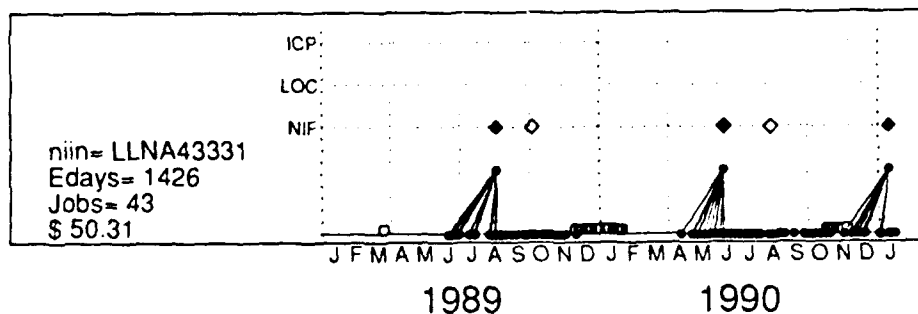


Figure 4.2—Complete Demand-Supply Profile

shows the full profile formed by adding this information to the partial profile in Figure 4.1.

The complete profile has three dotted horizontal lines above the request-issue plot. The "ICP" line is used to show ICP procurement actions and receipts (this information is not available from all ICPs). Similarly, the "LOC" line is used to plot local procurement contracts (as noted earlier, APADE data contain a purchase date but not a receipt date). When this information is available, an open diamond is used to indicate a request, and a filled diamond is used to indicate a received shipment.³ As can be seen, the part profiled had no local procurement, and since this part is locally manufactured, no action was taken by ASO. The third line, "NIF," shows NIF store activities; an open diamond indicates a NIF store requisition for the part, and a filled diamond indicates a NIF store receipt for the part. For the part profiled, it can be seen that each set of issues to deferred requests corresponds to a NIF store receipt, as would be expected. However, note that although the NIF store ordered the item in mid-October (i.e., the NIF store did not wait until the part was out of stock to reorder), the request took almost nine months to satisfy.

The demand-supply profile is complex and thus requires close attention to interpret. However, because it portrays the dynamics of demand and supply for each part, it offers much insight into the roles of the various supply organizations.

RESULTS

Of the 2109 different parts in the NIMMS data, 1587 had at least 1 day of delay between a requisition and the corresponding issue. To focus the analysis, only the top ten problem parts from each of the four main ICPs, ranked by number of engine days of delay,⁴ were considered. The analysis was further restricted to items used in at least ten different engine jobs.

³It is worth emphasizing that this convention diverges slightly from the way artisan requests are represented. For artisans, a single filled circle means that an artisan request was satisfied by an immediate issue from the NIF store. For requisitions for resupply of the NIF store, local procurement, and ICP actions, an open diamond indicates a requisition or procurement, whereas a filled diamond indicates the *receipt* of previously ordered parts. These events may not be in the available data, or one of the events may occur outside the time window of the NIMMS data.

⁴The use of this measure anticipates the needs of the next analysis (Section 5): engine days of delay are, as stated earlier, the amount of time an unavailable part holds down an engine job.

Both demand-supply profiles and boxplots are used here to display the results. The demand-supply profiles for the ICPs reveal a variety of patterns for the problem parts. Overall, however, two basic patterns emerge: (1) some parts—particularly ASO-managed reparable (cognizance code 7R)—had a fairly constant delay for each requisition; and (2) other parts—mostly consumables stocked in the NIF store—had periods during which the NIF store was out of stock alternating with periods where the part was available from the NIF store. The time that elapsed until the NIF was restocked varied widely.

Local procurement played a role for only three parts from these sets, and most of the delays appear to have been unrelated to lack of stock at the ICP, because issues for unfilled demands at the depot were rarely tied to ICP receipts. The delays for all items are shown as boxplots for all issues (i.e., unresolved requests are excluded) that took 1 or more days to receive. In terms of engine days of delay, ASO-managed consumables (cognizance code 1R) seem to have caused the most problems, although one ASO reparable (item 011510836) had the maximum engine days of delay: 6478. The delays for two DISC-managed and two OCALC-managed items fall within the range of delays caused by the top ASO consumables, but the other DISC and OCALC items trailed all of the ASO consumables in delays.⁵

ASO Reparables (7R)

Figure 4.3 shows the demand-supply profiles for the top ten problem ASO reparable. The first point to notice is that, with the exception of those for items 012458178 and 012458176 (discussed below), the profiles show that requests for parts were met with relatively constant delays.⁶ The demand for many of these parts was fairly steady (i.e., the requests were fairly evenly spaced and spread across both years)—particularly for items 011510836, 010037188, 010446885, and

⁵Items transferred from the services to DLA tend to be common-use items, many of which have commercial equivalents and thus are more easily procured.

⁶As noted previously, reparable are *not* stocked in the NIF store. Instead, they are provided from the local NSC (if in stock there) or from some other supply activity. Also, repair by the depot itself is another important source of reparable. However, the data do not indicate whether a requisition was satisfied by repair.

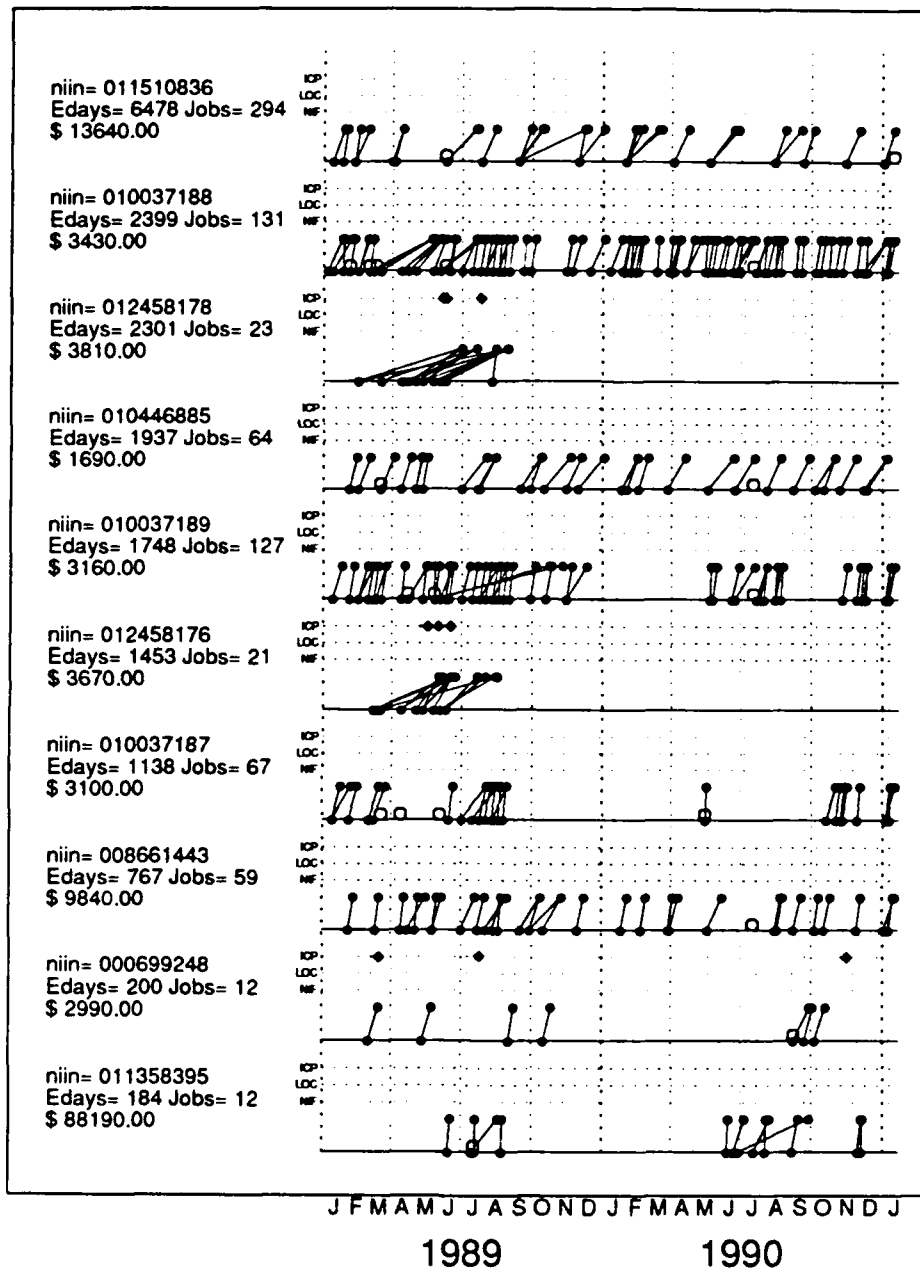


Figure 4.3—Demand-Supply Profiles for Top Ten TF-30 Problem Repairables Managed by ASO (7R)

008661443—and each of these parts was used in a substantial number of engine jobs (from 59 to 294). In addition, only item 000699248 had any ASO receipts during the 2 years covered by the data, and those do not appear to have affected the time the part took to reach the depot.

The actual distribution of delivery times, which is hard to determine from the demand-supply profiles, can be seen in Figure 4.4, the boxplots of delivery times. For many of these parts, the plots show a surprising spread of delivery times. For most parts, however, the number of requisitions that took more than 12 days is a significant proportion. In addition, some demands took a long time to fill, sometimes remaining unfilled even while other demands for the same item were being filled in the meantime (see items 010037189 and 011358395). As was true for the demand-supply profiles, none of these delays seems to have been related to procurement activity: all items supplied seem to have come from within the supply system.⁷

The two exceptional parts, 012458178 and 012458176, differ from the others in two ways. First, as Figure 4.3 shows, they were demanded only in the first half of 1989; in fact, they were ordered for roughly the same set of jobs. The supply system seems to have been out of these parts, because no issues were made until a set of receipts was logged by the ASO procurement system. Note that there is a fairly long gap (at least a month) between the final receipt (last filled diamond on the ICP line) and the final issue at the depot.

ASO Consumables (1R)

Figure 4.5 shows the demand-supply profiles for the top ten problem consumables managed by ASO. These profiles differ considerably from those for the ASO reparable, the predominant pattern being periods when the NIF store was out of the part alternating with periods when the issue time was 1 day or less because the part was in stock at the NIF store.⁸ Virtually all periods when the NIF store was out of stock ended on a day in which a receipt was logged by the NIF store and many outstanding requisitions were satisfied by issues.

⁷Unfortunately, the NIMMS data are not very helpful for determining a particular part's origin. The location field on receipt transactions should indicate the part's shipping point, but for most transactions this field shows the code for the Norfolk NSC. What happens is that parts out of stock at the Norfolk NSC are usually routed from their point of origin through the Norfolk NSC, and NIMMS treats this last location as the part's source.

⁸Interestingly, all the ASO-managed consumables that were problems seem to have been stocked by the NIF store at some time during the 2 years covered by the data.

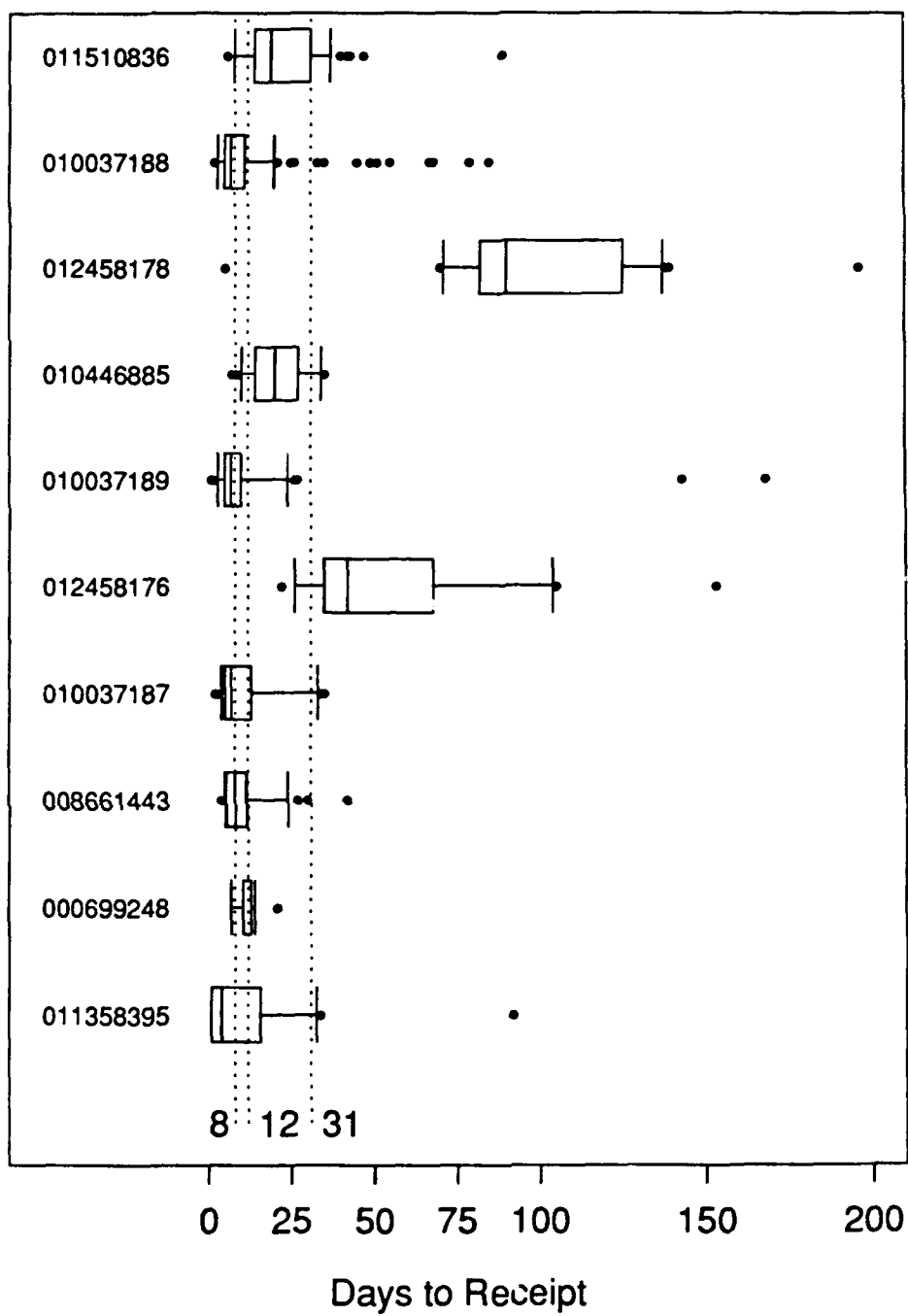


Figure 4.4—Boxplots of Nonzero Delivery Times for Top Ten TF-30 Problem Reparables Managed by ASO (7R)

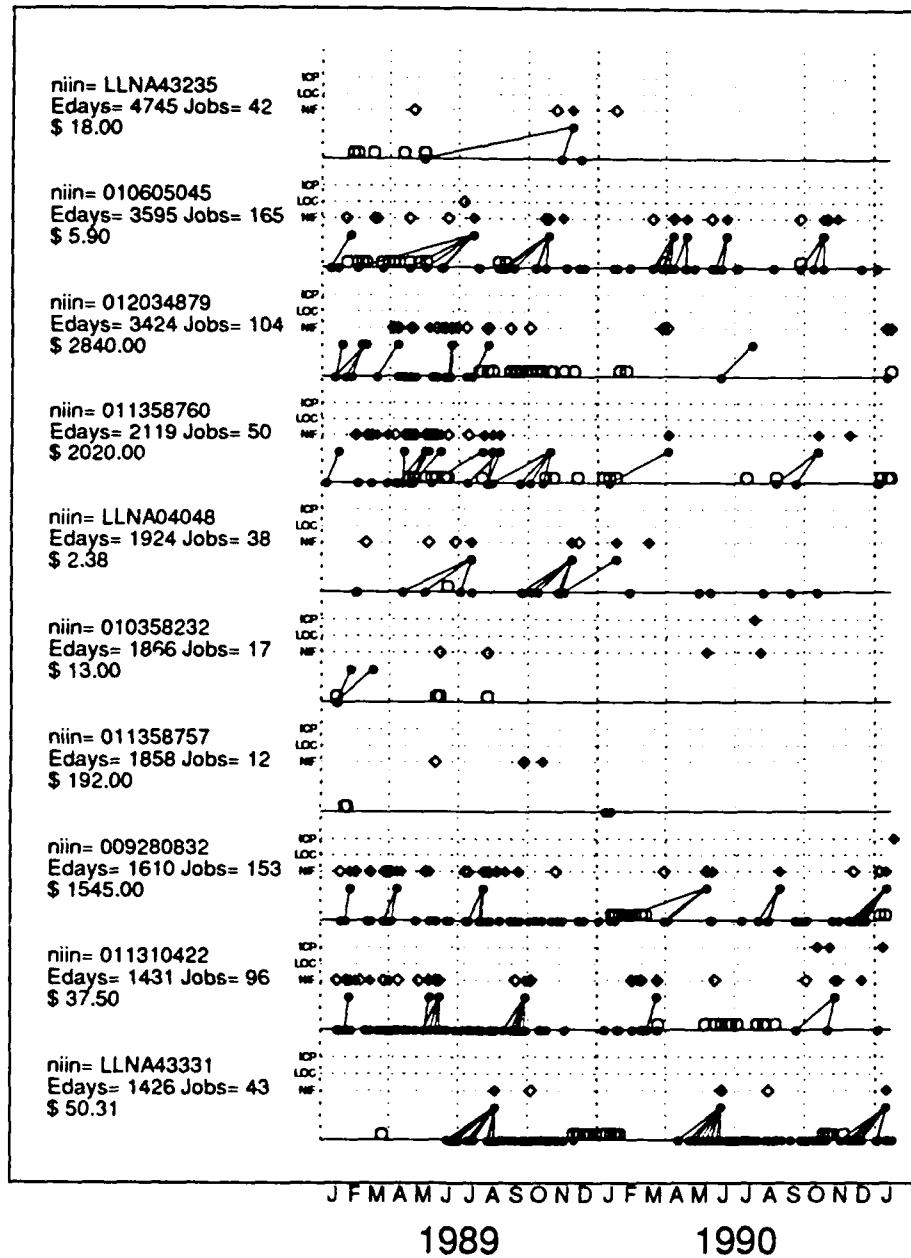


Figure 4.5—Demand-Supply Profiles for Top Ten TF-30 Problem Consumables Managed by ASO (1R)

The profiles for these consumables contain many more unresolved requisitions than do the profiles for the reparables. Further, the unresolved requisitions seem to be clustered at times when local supplies of parts had run out: a period of issues from the NIF store was followed by a cluster of unresolved requisitions, possibly mixed with requisitions actually satisfied by an issue (see, for example, items 010605045, 012034879, 009280832, 011310422, and LLNA43331). We could not determine from the NIMMS data how these unresolved requisitions were in fact terminated. However, note the clear pattern for item LLNA43331 from the middle of 1989 on: the item was first in stock, but then there was a spate of unresolved requisitions, a gap in demands, and finally a series of requisitions that were ultimately resolved with an issue in mid-1990. We speculate that this was a situation in which other engines under repair were cannibalized to satisfy the unresolved requisitions, and then new requisitions were submitted for the cannibalized jobs. However, this clear pattern does not occur for any of the other problem parts.

As with the reparables, all but two of the consumables seem to have been in heavy demand, although the demand for the consumables was on the whole more sporadic.

Figure 4.6 shows the delivery times. Note that when ASO-managed consumables were out of stock, they took much longer to be issued than did out-of-stock reparables. The median delivery time for all consumables was over 12 days, implying either that the parts were not in stock at the local NSC or that the NSC took a long time delivering the part to the depot. In only two cases does the delay seem to have been caused by procurement activities (see Figure 4.5). First, for item 010605045, a local-purchase date was recorded in mid-1989 near the end of a quarter of unfilled demands. However, we could not determine when that local purchase was received, and two NIF store receipts follow the local action. Second, for item 011310422, ASO logged a receipt in late 1990 after almost half a year of unresolved requests and about a month before the NIF store recorded a receipt and satisfaction of two outstanding backorders. For all the other items, there is no evidence of either local purchase or receipt of the item by ASO. We infer that the delay was caused by having to locate the part elsewhere in the DoD supply system and get it to the depot.

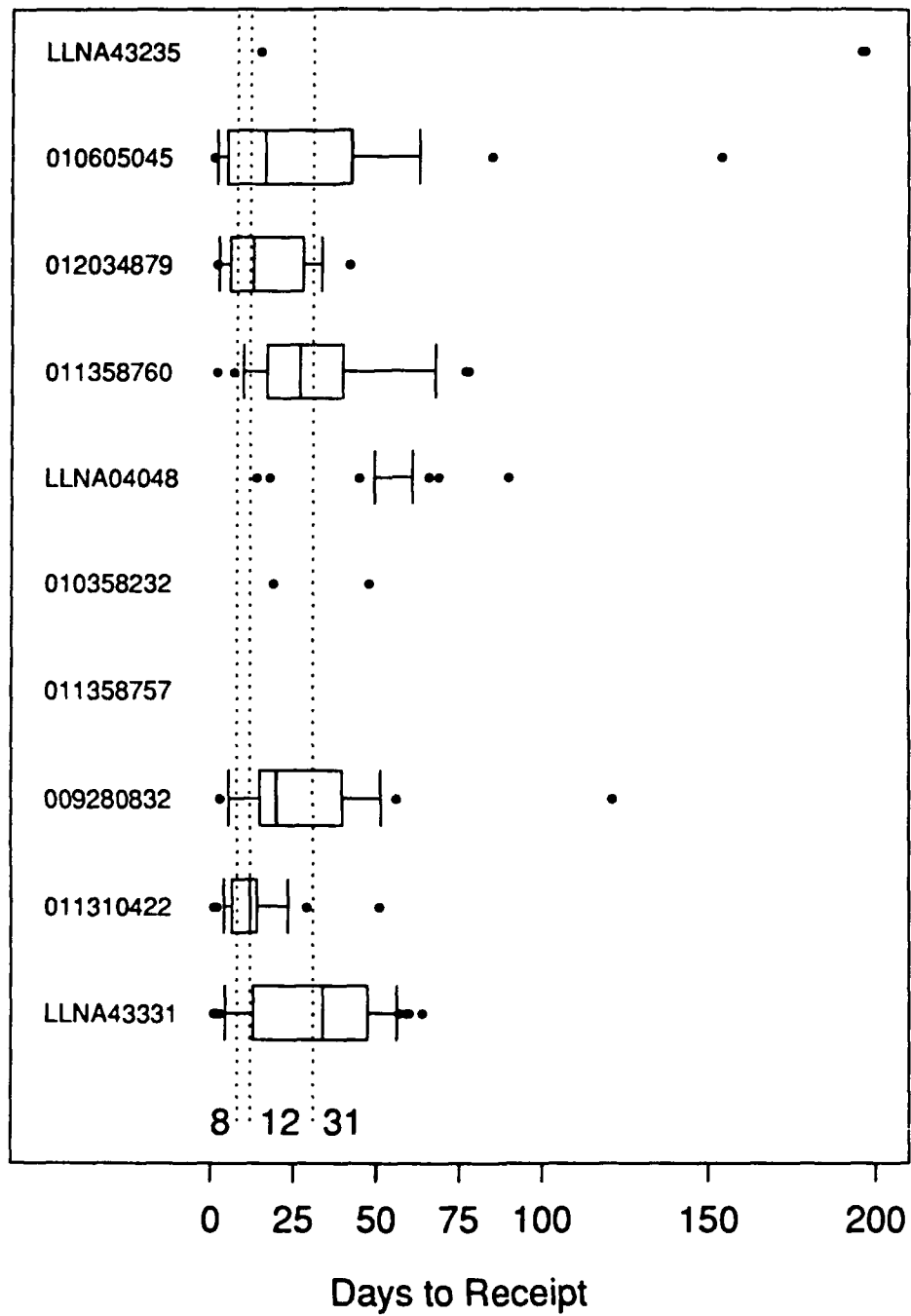


Figure 4.6—Boxplots of Nonzero Delivery Times for Top Ten TF-30 Problem Consumables Managed by ASO (1R)

DISC Parts (9Z)

Figure 4.7 displays the demand-supply profiles for the top ten problem parts managed by DISC, all of which are consumables. The pattern here resembles that for the ASO consumables: alternating periods of the NIF store having and not having the requested item. And, as was also true for ASO consumables, most of the DISC parts were in heavy but somewhat sporadic demand.

We did not have ICP information for three parts: 008943561, 011655078, and 008507832. As mentioned in Section 1, we had to request paper copies of DISC reports for each part. We made the request rather early in the study, and to keep the volume of paper manageable, we did not ask for reports on parts whose maximum delay over all engine jobs was less than approximately 30 days. At that time, we did not appreciate the impact such parts can have on engine repair.

For four of the seven parts for which we had information, our results were similar to those for the ASO-managed consumables: we found no indication of ICP involvement in solving parts-availability problems. The exceptions were item 000247114, for which a shipment in the last quarter of 1990 seems to have satisfied a set of requests ranging back to mid-1990; item 006418192, for which shipments at the end of the third quarter of 1990 satisfied the requests over 1990; and item 000223384, which had a series of unsatisfied requests over the last three quarters of 1990. From the DISC reports, we determined that a contract was awarded at the end of 1991 for this last part. It seems fair to say, then, that the problems with these three parts were a product of factors operating at the ICP level.

Figure 4.8 shows the boxplots of delivery times for the DISC parts. Delivery times seem to have been shorter on the whole for the DISC parts than for both types of ASO-managed parts (compare Figure 4.8 to Figures 4.4 and 4.6). Exceptions to this pattern are the delivery times for item 002563668, which was demanded only in mid-1989; items 001481194 and 000247114, which were the worst problems of the DISC-managed parts; and item 011689103, the requisitions for which seem to have been satisfied mainly by local procurement. (Note the correspondence between purchases and issues for 011689103 in Figure 4.7. Also note the fairly long time lag between purchase date and actual issue.)

OALC Parts (9J)

Figure 4.9 shows the demand-supply profiles for the top ten problem parts managed by OALC. The pattern here is quite similar to that for the DISC parts

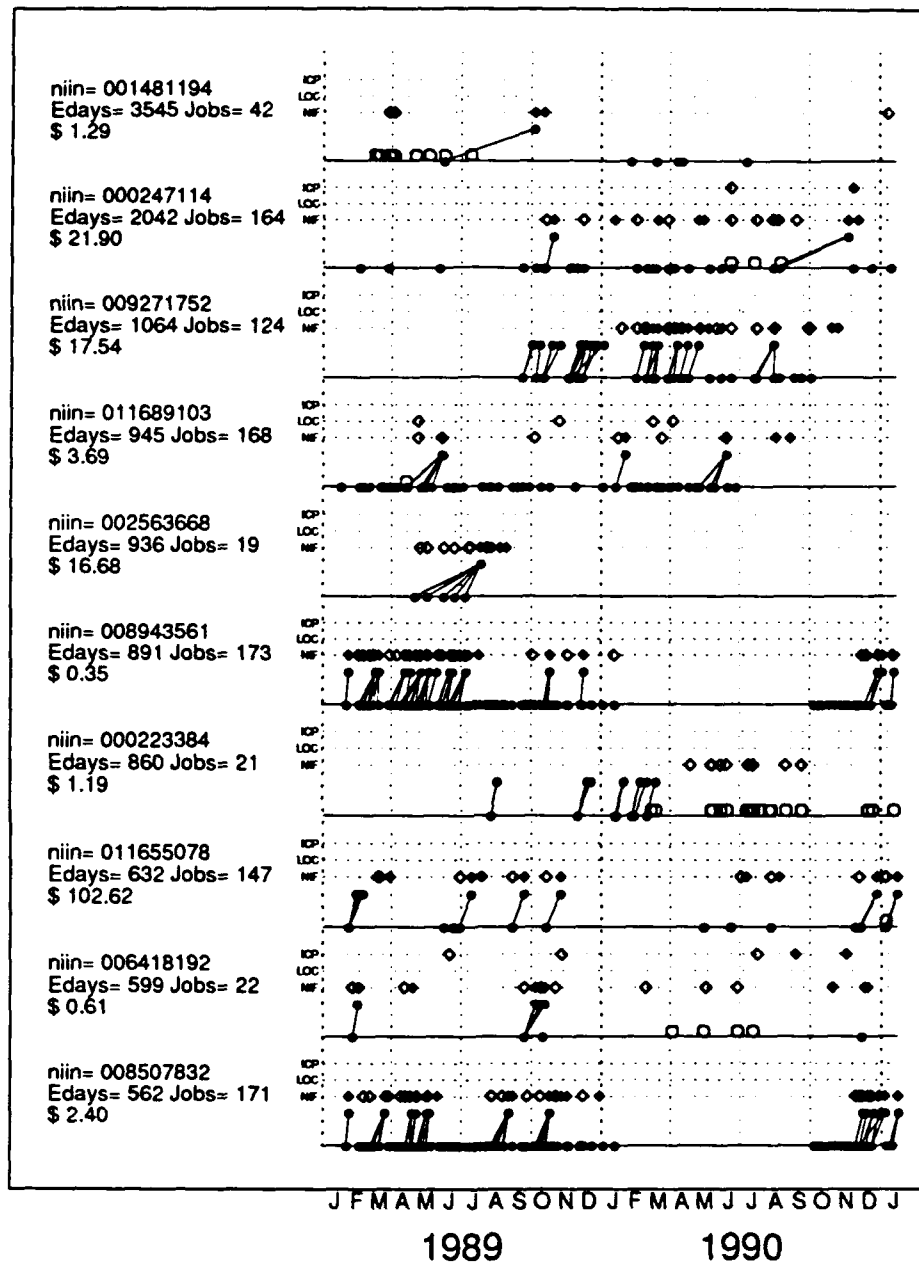


Figure 4.7—Demand-Supply Profiles for Top Ten TF-30 Problem Parts Managed by DISC (9Z)

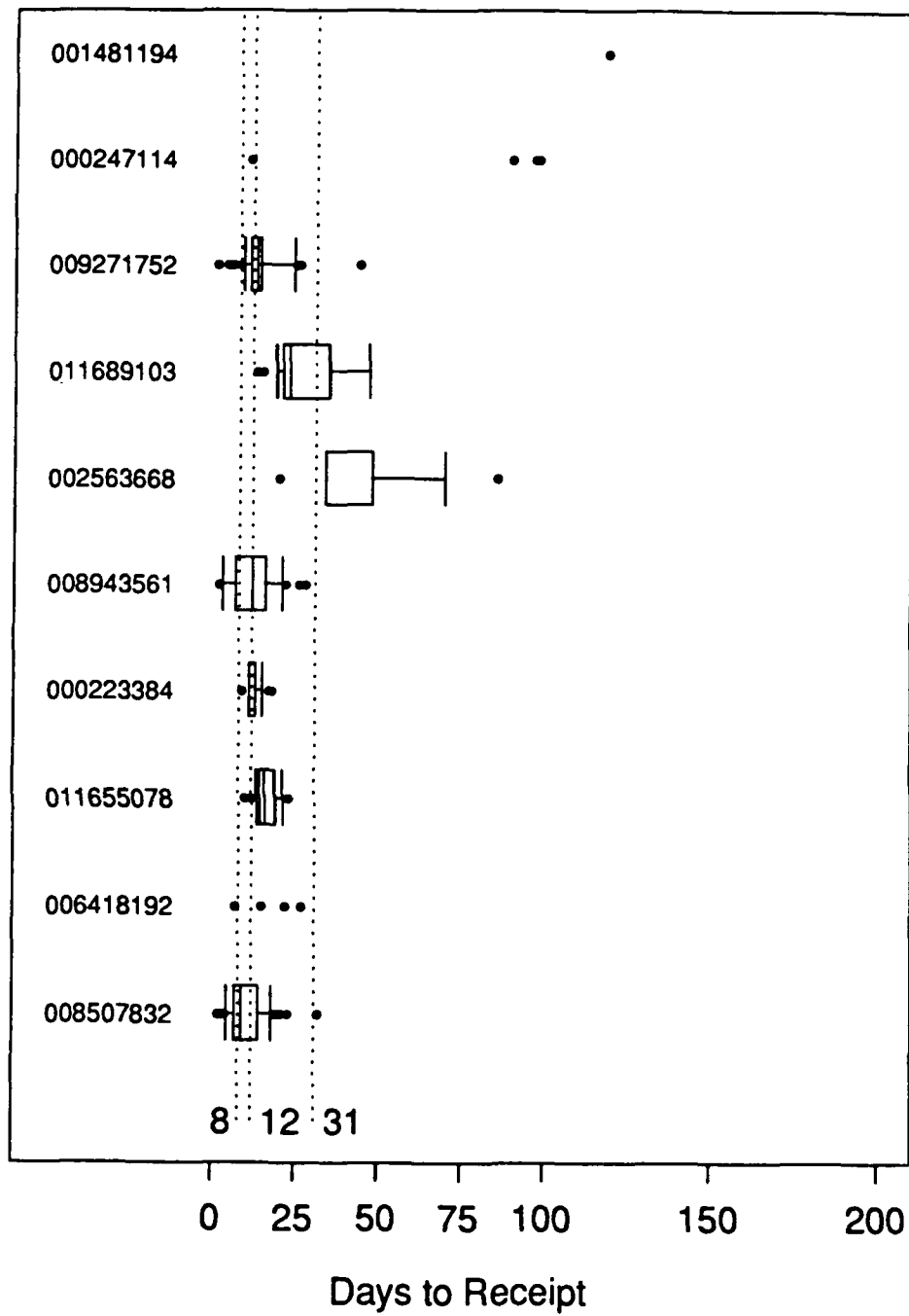


Figure 4.8—Boxplots of Nonzero Delivery Times for Top Ten TF-30 Problem Parts Managed by DISC (9Z)

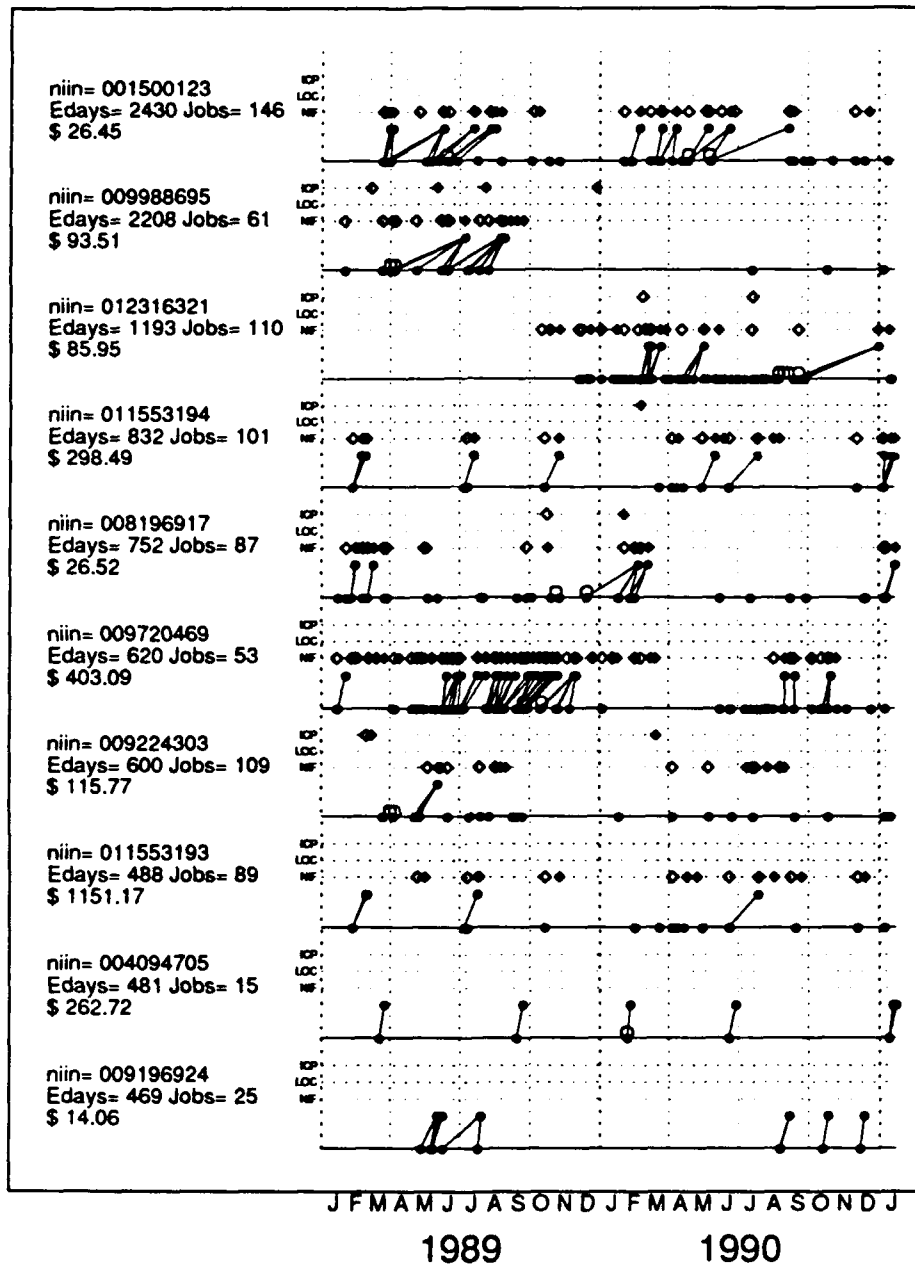


Figure 4.9—Demand-Supply Profiles for Top Ten TF-30 Problem Parts Managed by OCALC (9J)

and the ASO consumables: parts were in stock, then ran out, and then were back in stock (being issued again) after a variable period of time. As was true for the DISC parts, few requisitions were unresolved, but delivery times (see Figure 4.10) were quite a bit longer than those for DISC parts and more closely resemble those of the ASO consumables. Note that parts 004094705 and 009196924 do not seem to have been stocked in the NIF store; their profiles resemble those of the ASO reparables (compare Figure 4.9 with Figure 4.3).

As noted in Section 1, we acquired annual procurement data for the parts managed by OCALC. Unlike the ASO procurement history, however, the OCALC data did not include records of item receipts, so we could not tell if a particular delivery date had been slipped or advanced or if there had been multiple deliveries for a single contract.⁹ However, there are a few points to be noted about ICP receipts for parts managed by OCALC.

Five OCALC parts had deliveries scheduled for the 2 years covered by the data. Of these five, one in particular, item 009988695, clearly seems to have had a delivery that filled some outstanding demands. Such a delivery may also have occurred for part 012316321. Two deliveries (corresponding to the two orders shown) were scheduled for February and March 1991 for this part. They do not appear in the demand-supply profile, which covers only up to January 23, 1991, but two NIF store receipts of this part do occur during early January. These may have been the awaited shipments, expedited because of Operation Desert Shield/Storm. The record for part 008196917 shows a receipt just before a Norfolk NIF store receipt and issue, but the delay experienced by that requisition seems typical of the later profile for that part. For the other two parts in the top-ten list, 011553194 and 009224303, the scheduled receipts do not seem to have been closely associated with the satisfaction of a set of outstanding demands. As with the parts managed by ASO, then, we drew the tentative conclusion that only a portion of the problem with parts managed by OCALC is caused by ICP procurement activities.

Norfolk did not locally procure of any of the top ten OCALC-managed parts.

CONCLUSIONS

Our examination of the demand-supply profiles brought us to some tentative conclusions that, in turn, suggest directions for further investigation of new options

⁹The data set records modifications to contracts and the resulting first deliveries for the modifications.

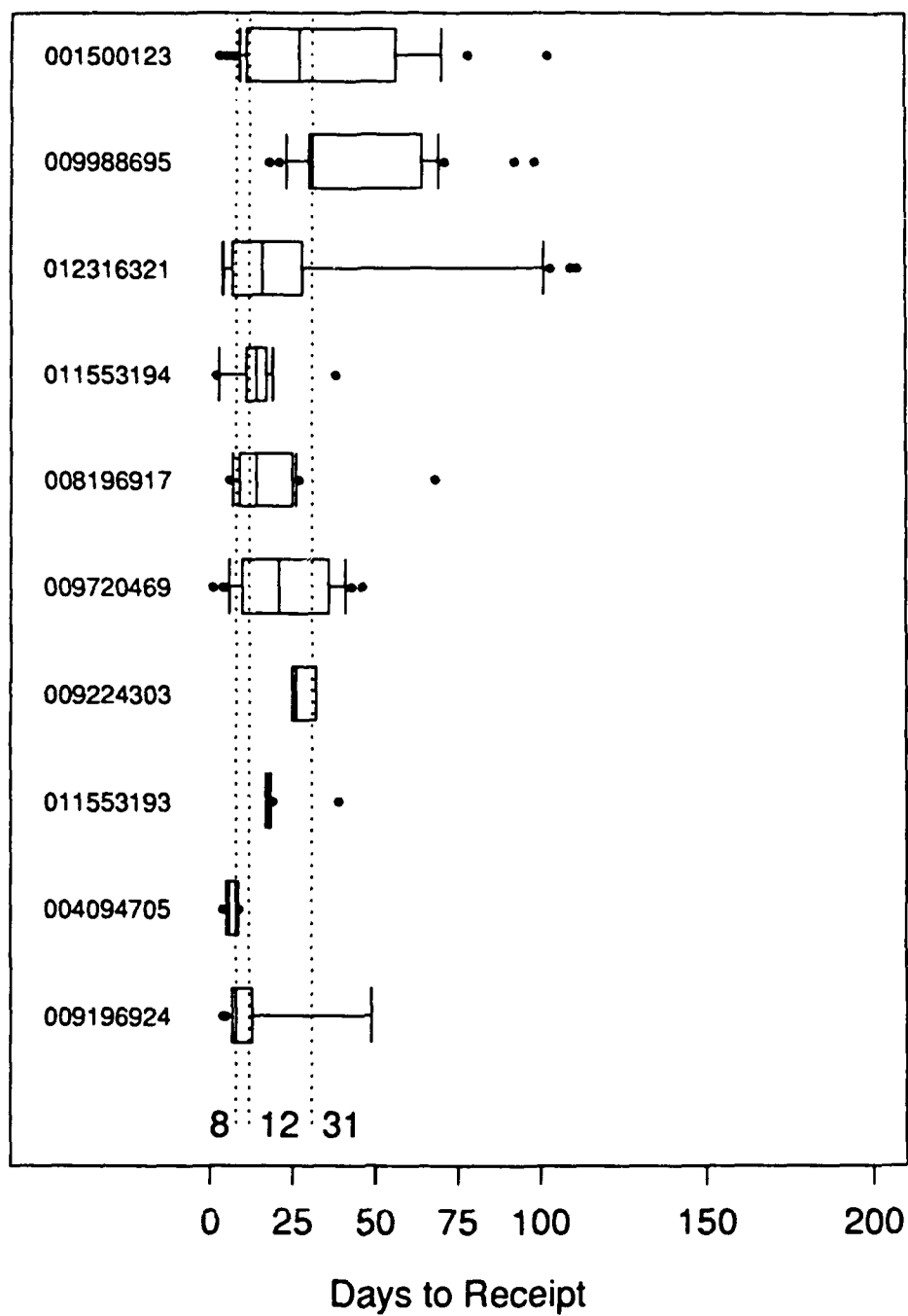


Figure 4.10—Boxplots of Nonzero Delivery Times for Top Ten TF-30 Problem Parts Managed by OCALC (9J)

for materiel management and for more sophisticated analysis of the materiel problem. These conclusions and the directions they suggest are as follows.

First, and most important, the impact of the problem parts studied is largely attributable to many requisitions being moderately delayed, not a few requisitions being delayed a very long time. With few exceptions, most delays for parts managed by ASO and OCALC do not appear to have resulted from a lack of stock at the ICP level (i.e., situations in which a part is unavailable throughout the entire supply system and must be procured). Instead, the delays seem to have arisen when the NIF store was out of or did not stock an item and the item had to be delivered from another segment of the supply system. Delivery in these cases took between 12 and 40 days for a substantial percentage of the requisitions.

Unfortunately, this finding does not pinpoint the source of the problem. If the item is in stock at the local NSC, this delay seems too long. If the item is not in stock there but is elsewhere in the DoD supply system, where is the delay occurring?

If the part is in the DoD supply system, the delay could be in finding it, in preparing it for shipment, in transporting it, or in processing the receipt. The NIMMS data cannot provide insight into the cause of the delay. It would be of some interest to compare the delivery processes for consumables managed by ASO and OCALC with the delivery processes for those parts managed by DISC, since delivery times for DISC parts seem to be somewhat shorter. However, all the delivery times are unacceptable in terms of the engine days of delay they entail.

5. ANALYSIS OF IMPACT ON REPAIR TIME

According to the third perspective, which is that of the senior depot management, a delay in getting parts to the depot is important to the performance of the engine repair process if parts are "holding down" a large number of engines, preventing their repair from being completed. There is good reason for this view: the depot is paid only when repairs are completed and engines are returned to the supply system in ready-for-issue (RFI) condition, and the senior depot management is responsible for ensuring that the depot operates efficiently.

Relles¹ has argued that engine days of delay attributable to unavailable parts should be the measure of materiel support in the broad sense because engine repair time is really the primary quantity of interest to the Navy as a whole. He contends that for every day an engine is in repair, the Navy loses an engine day needed to cover operational requirements.² In Relles's work, this concept allows a price to be put on a day of turnaround time and hence provides a yardstick for measuring proposed improvements to the repair process, such as buying stocks of spare parts in anticipation of repair.

The approach we chose for our third analysis was to use engine days of delay to quantify the impact of materiel support problems on engine repair.³ Our use of this approach was anticipated in our second analysis: the parts selected for the demand-supply profiles were those that had caused the most engine days of delay and that had been used in at least ten different engine repair jobs.

DESCRIPTION OF ANALYSIS

Given the lengthy delays for some requisitioned parts, we decided to examine the delays attributable to parts and to determine whether those parts affected a

¹D. R. Relles, unpublished research.

²This concept ignores the problem of whether an engine in repair is in fact needed by the Navy, either for operations or as a spare. The question of need, while important, was beyond the scope of this Note; we assumed that repair had been authorized to cover an actual need.

³This measure can be easily converted to the one used by Relles, which equates the value of a year of engine availability to the price of the engine. However, assignment of a dollar value to an engine day of delay is still the subject of ongoing work. As a simple illustration of some of the difficulties involved in making such an assignment, consider the fact that since the TF-30 is no longer in production, there may be some disagreement about the proper price. The engine originally cost about \$250,000, but its current price would probably be about \$1.2 million.

substantial number of engine jobs. Instead of focusing on individual requisitions, as in our analysis of demand-supply profiles, we looked at all the requisitions for a given item and added up the time needed to satisfy all requisitions for that item for each engine job. If there were several requisitions for an item for one engine job, we counted any overlaps in delays only once in computing the total delay for the job. For each part, the delays it caused for all jobs in which it was required were summed to produce its total number of engine days of delay.

This approach assigns full "blame" for each engine day of delay to each unavailable part. For our investigation, such an approach seemed reasonable, because our interest was in identifying problem parts and trying to determine why they took so long to be issued. Since any repair job cannot be completed without all needed parts, we wanted to look at those parts that were responsible for most of the engine days of delay. Even though some jobs were waiting for other parts as well, we wanted to assess the individual impact of each part.⁴

The other measure of an unavailable part's impact is the number of engine jobs for which the part is required, since a part that holds down a few engines is not as important as one that holds down many engines. These two measures, engine days of delay and jobs per part were used to screen the parts requested in the set of TF-30 jobs and to select problem parts for close inspection.

An implicit assumption in our analysis was that a delay in getting a particular part is equivalent to a delay in finishing an engine repair job. Recall that the NIMMS data set only has materiel transactions in it; it does not explicitly indicate when an engine job starts or finishes. Many tasks in engine rework (e.g., plating and grinding operations) do not consume spare parts, and at least one source of parts is not reflected in the NIMMS data: artisans sometimes cannibalize in-work engines to complete jobs that are awaiting parts.⁵ However, the Navy's policy is to minimize cannibalization, primarily because of the potential safety hazards of moving used parts between engines.

⁴In an unpublished study, Relles gives an alternative view of assessing the impact of individual parts on repair.

⁵NIMMS has a transaction for recording cannibalizations, but we found that it was rarely used: in *all* of our TF-30 data—both engine and component repair—only three cannibalization transactions were recorded. However, we were told by many depot workers that cannibalization is frequently practiced to help meet repair deadlines.

RESULTS

Our first goal was to produce an overall picture of how the delay of individual items affected total engine repair time. For each part in the NIMMS data for TF-30 engine jobs, we computed the total time each job was delayed in waiting for that part and then summed those delays over all jobs. For unresolved requisitions, we used the estimate described in our analysis of demand-supply profiles: the "issue" date for the part was taken to be the last transaction in that job or the next issue of the same part to satisfy another requisition, whichever came first. In addition, we used only requisitions with 1989-1991 issues, as we had done in the other two analyses.

Figure 5.1 plots engine days of delay versus the number of engine jobs for each of the 2109 parts. It is clear that a substantial number of parts had total delays of greater than 1000 days and that most of these parts were used in a substantial number of jobs. Cognizance codes accompany the most extreme points. As can be seen, most of these are ASO cognizance codes, although a few are those of OCALC and DISC. These parts were the leaders on the top-ten lists for the ICPs (see the demand-supply profile analysis in Section 3).

Figure 5.2 shows the data from Figure 5.1, but here we have kept only the points representing parts for which the respective repair job was delayed fewer than 1000 days. In addition, the plot is divided to show the average number of days of delay per job. Note that a large number of parts have an average delay of 5 or more days (1 work week or more). If repair jobs stop until these parts arrive, the repair process will be severely disrupted. And items that average more than 20 days to receive and are used in a substantial number of jobs should certainly be looked at more closely in an effort to pinpoint and remedy the causes of delay.⁶

Figure 5.3 again shows items with delays of fewer than 1000 days, this time broken down by the responsible ICP. Note that few ASO reparable in this category were heavily used but that the delays for those that were used could be long. Note also that both DISC and OCALC had some parts that caused long delays and were fairly heavily used (more than 50 jobs apiece). Finally, note that the other ICPs also contributed some problem parts.

Together, Figures 5.1, 5.2, and 5.3 provide an overview of the impact of specific parts on engine repair times and indicate that a substantial number of parts are

⁶Parts that hold down relatively few engines may still be important. For example, if there is little overlap among needed repair parts for different jobs, a collection of parts, each delaying a few jobs, can be holding down a large proportion of the total jobs.

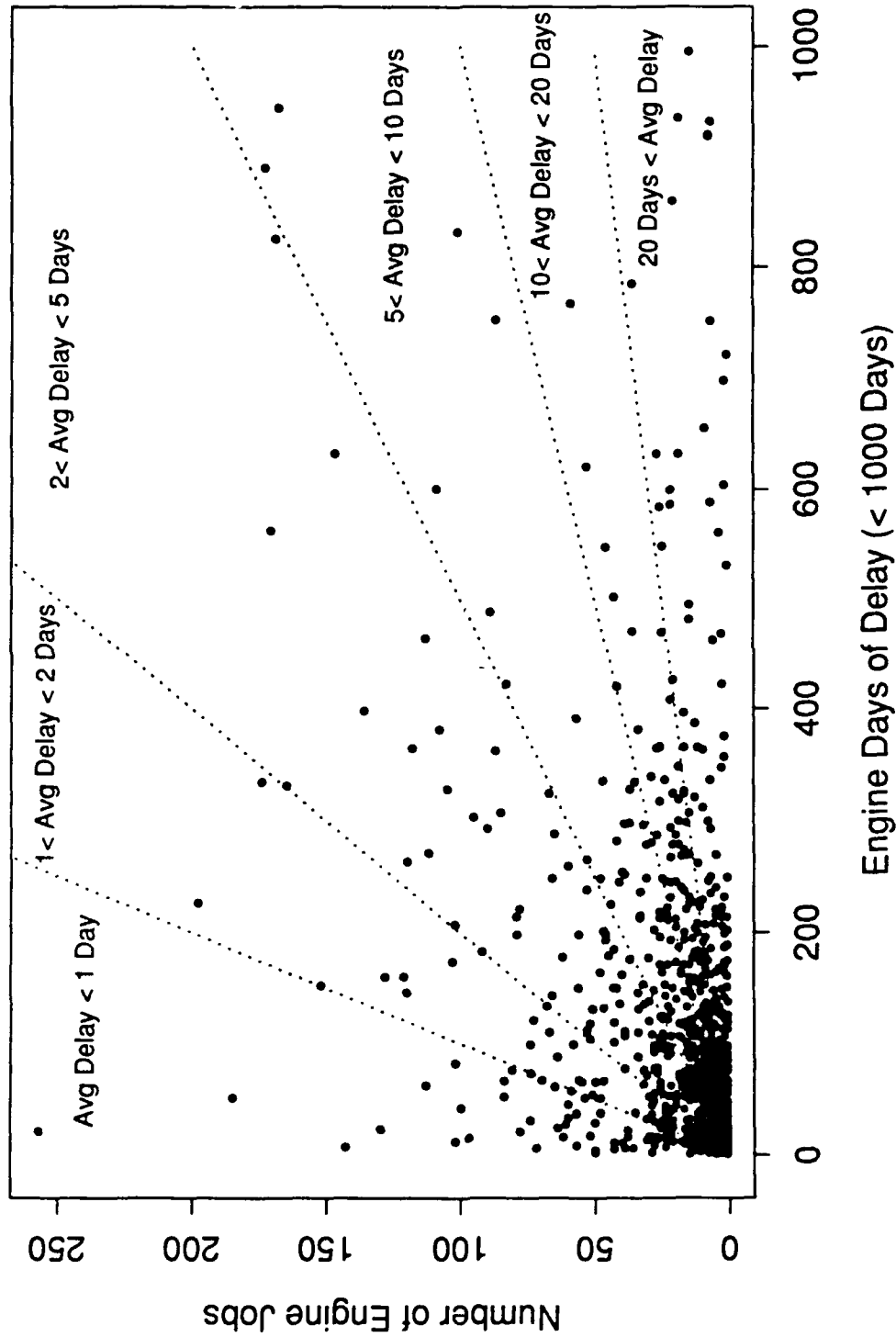


Figure 5.2—TF-30 Engine Days of Delay Versus Number of Jobs with Average Delay Regions Indicated

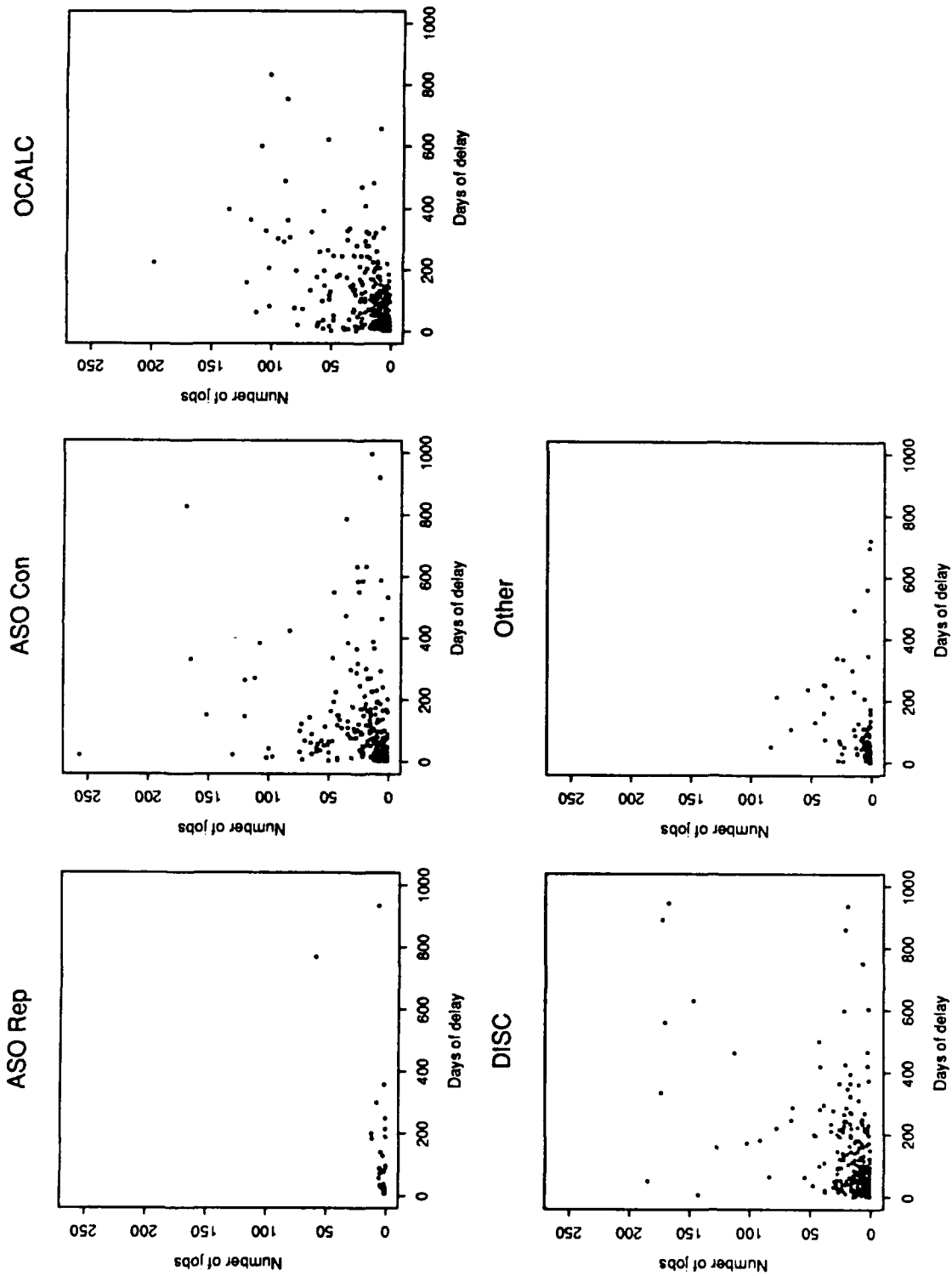


Figure 5.3—TF-30 Engine Days of Delay Versus Number of Parts for Major ICPs

causing long delays. These graphs can, however, be misleading in one important way: when cannibalization is excluded, the pacing item for a repair job is the part that arrives last. In other words, a repair job cannot be completed in less time than is needed to receive the pacing part. It is conceivable that each engine job represented in the figures is being held down by a part demanded by that job alone, and that parts appearing to have a heavy impact actually form a "core" of delays that are not the longest delays for the engine jobs.⁷ This possibility is extremely important in deciding how to attack the materiel problem. If it is truly the case, putting a great deal of effort into better provision of heavy-impact parts will have *no effect whatsoever* on total engine repair time. Instead, a two-pronged approach is needed. That is, if the amount of time engine jobs spend waiting for parts is to be decreased, we need to identify how much of the problem is caused by the rather small collection of heavy-impact parts and how much is caused by parts that are pacing only a few engine jobs each.

With this approach in mind, we looked at the data to find the part with the longest delay for each of the 451 engine jobs in the data set. The parts were then ranked in order of their overall impact on the 451 engine jobs. Table 5.1 lists the top ten problem parts in terms of overall impact.

Table 5.1
Number of Maximum Delay Jobs for Heavy-Impact Parts

NIIN	ICP	Number of Jobs for Which Part Caused Max Delay	Percentage of Jobs with Max Delay	Total Engine Days of Delay (All Jobs)	Total Jobs in Which Part Used
011510836	ASO(rep)	22	4.9	6478	294
LLNA43235	ASO(con)	28	6.2	4745	42
010605045	ASO(con)	14	3.1	3595	165
001481194	DISC	11	2.4	3545	42
012034879	ASO(con)	24	5.3	3424	104
001500123	OCALC	10	2.2	2430	146
010037188	ASO(rep)	7	1.6	2399	131
012458178	ASO(rep)	7	1.6	2301	23
009988695	OCALC	5	1.1	2208	61
011358760	ASO(rep)	3	0.7	2119	50
Total		131	29.1		

⁷This phenomenon is sometimes referred to as the "longest-pole" effect.

CONCLUSIONS

As can be seen, the heavy-impact parts are the pacing parts for almost 30 percent of the 451 engine jobs, and these parts are also used in a large number of jobs. This finding implies that attention paid to these heavy-impact parts could have a substantial effect on engine repair time, both on pacing items and on the set of "next largest" delays.

An extension of this table reveals that 66.5 percent (300) of the engine jobs were paced by 56 different items. However, the final 33.5 percent (151 engine jobs) were paced by 125 different items, which, in addition, varied greatly as to the total number of jobs in which they were used. The materiel problem therefore needs to be attacked from two directions. First, the causes of the delays associated with the relatively few heavy-impact items, which include the ones on the top-ten lists discussed in Section 4 and which paced two-thirds of the engine jobs, need to be determined. Second, for the substantial percentage of jobs held down by parts that were not holding down many other engine jobs, the demand-supply profiles and ICP information for each part need to be examined in detail to determine what causes the parts delays.

6. CONCLUSIONS AND RECOMMENDATIONS

The Navy is leaving a decade in which the personnel and materiel resources available for supporting a large and varied force were abundant. Changes in the probable threats to national security, coupled with domestic budget problems, are causing sharp cuts in both combat forces and support resources. The short-term rapid reduction of personnel will put extreme pressure on the Navy to make efficient use of remaining personnel. The likely mid-term situation is a stable but smaller force, and a substantially slower fielding rate for new weapon systems as more and more attention is given to repairing, modifying, and incrementally enhancing weapon systems already in service.

The reductions in forces and equipment will probably mean that the stock of spare parts will be adequate for the short term, since demand will lessen and parts may be available from scrapped weapon systems. Efficient use of these parts in the short term will require an emphasis on the management of on-hand assets, rather than on procurement. However, as the force stabilizes and the temporary overstock is reduced, the emphasis will have to balance between managing the remaining assets well and providing an efficient procurement process.

CONCLUSIONS

Because the exact set of parts required to repair an engine (or other item) is not known in advance, the provision of spare parts is a difficult problem. Completion of a repair job requires 100 percent of the needed parts, leading to the longest-pole effect in that the part requiring the longest wait paces the job. This complexity means that our analysis, based on a two-year set of NIMMS data, must be considered tentative and preliminary. However, we can draw a number of conclusions that provide a basis for starting action to solve the materiel problem and for gathering more information.

First, the total engine days of delay for which a part is responsible is a good measure for determining which parts are the primary culprits in holding up repair. Six parts on our top-ten lists of parts causing the most engine days of delay were responsible for the maximum delay in 25 percent of the engine jobs.

Second, the problem parts can be divided into two categories according to their impact on the depot work load. A small subset of these parts caused a clear majority

of the delays: 56 of the 2109 parts ordered in the data set were responsible for the maximum delay of two-thirds (300) of the engine jobs.¹ The remaining one-third (151) of the engine jobs were paced by 125 different items, some of which were demanded for many jobs, and some of which were demanded only by the job they delayed. Therefore, alleviating the delay for a small set of parts could lead to substantially lessened engine repair time. Doing so would not, however, help the substantial minority of engine jobs awaiting other parts.

Third, there seem to be two types of supply problems, regardless of whether a part is one of the troublesome minority that affects many jobs or one of the group that affects only a handful of jobs. For 7 of the 40 parts in the top-ten lists, the supply problem seems to be in the procurement end of the DoD supply system, as evidenced by the concurrent resolution of outstanding requisitions with deliveries of the part in response to ICP orders. The delivery times for some of these parts were quite lengthy. Since a minority of the second group of problem parts also showed quite lengthy delays, we suspect that those parts, too, were not in stock in the DoD supply system and had procurement difficulties of some kind. However, the remaining 33 parts in the top-ten lists were affected by the second type of supply problem: they were sometimes in stock at the NIF store and sometimes not, but when they were not in stock, they often took on the order of 20 to 30 days or more to receive and issue. The fact that these delays were well below the time required for most procurement actions, coupled with the observation that these requisitions were not resolved contiguous with local procurement actions and/or deliveries to an ICP, led us to presume that the parts were in stock somewhere in the DoD supply system and that the wait was attributable to shipping, administrative, and/or handling delays. We did not analyze all parts in the same detail as the "top 40," but we suspect that problems with other parts would have been very similar.

ASO reparable were a special case (and a good example) of the second type of supply problem. Although only five of them were in fairly heavy demand, those five were responsible for a large share of engine days of delay because each demand took 8 to 12 days to fill. Our assumption is that the reparable were in stock at the local NSC and that the delays occurred in shipping the parts from the NSC to the depot.

¹The 56 included 39 items from the four top-ten lists, plus some ASO consumables whose total engine days of delay exceeded the delay attributed to items from DISC and OCALC.

RECOMMENDATIONS

Our findings led us to four recommendations for the Navy. The first two pertain to finding the detailed causes for the delays uncovered in our analyses. The second two describe efforts that could improve the existing data sources to make them more useful for the supporting analysis needed for the first two recommendations.

1. The Navy needs to reduce the delay involved in getting parts to the depot when those parts are in stock in the Navy or DoD supply system. Our analysis indicates that this reduction would greatly decrease the time required to complete engine repair jobs. There are three main areas to be addressed.

First, an analysis is needed to determine why getting requested parts from off-station takes so long. The most important task is to see where the delays occur in the different segments of the supply pipeline. Possible causes of delay (and it is likely that there are several) include the difficulty in finding a part in the Navy or DoD supply system, a long wait for military transportation, lengthy administrative procedures for authorizing release of parts, individual shipments being held at supply depots until an economical load is built up, and time-consuming procedures for logging in receipts of shipments. A detailed analysis of this nature will require access to information sources other than the NIMMS data, which can identify the parts to track closely but cannot identify delay sources.

No solutions should be formulated until this analysis is done, although solutions might be quite clear once the relative delays are identified. For example, if locating parts causes the longest delays, a Navy- or DoD-wide parts-locator information system might be very useful. In other cases, the solution might be to initiate new performance measures to provide appropriate incentives for improved performance.

The solution for one delay seems to be quite clear already. Our analysis of the ASO-managed reparables suggests that it may make sense to stock some of these items in the depot (perhaps in the NIF store) for immediate issue, as is currently done with consumables. Such a policy should make it possible to drastically shorten the supply pipeline for these parts.²

²In informal conversations, Navy personnel have argued that the stock should be kept at the NSC to service other demands (such as intermediate-level repair at Naval air stations or on board aircraft carriers). The expense of the reparables is also cited as a reason for not keeping them at the depot. Neither reason seems important enough to outweigh the benefits to be gained from keeping a small local stock in the depot itself.

The second area to be addressed is the possibility that modified NIF-store stocking rules might lead to a higher percentage of orders being filled directly by the NIF store, thereby reducing the need to go off-station for parts. Experiments along this line have been conducted over the past year at NADEP Norfolk and have reportedly been quite successful.³ The NIMMS data, as we used them, provided little insight on this matter, although the demand-supply profiles indicate that in many cases the NIF store ordered well in advance of stockouts. However, as with other parts requests, the time taken to fill a NIF store requisition was often long.

Finally, the Navy needs to assess other methods of planning and of ordering parts (such as forecasting based on anticipated repair) to see whether parts availability can be improved. Any improvement along these lines depends strongly on the characteristics of individual parts and will probably vary for different end items.⁴ Moreover, no such improvement can guarantee that there will never be a stockout at the lower levels of the supply system. An efficient delivery pipeline from off-station will thus probably always be needed to cover emergencies (although a reduced frequency of emergencies because of improved parts availability might make commercial transportation more attractive than a dedicated DoD fast transportation system).

2. The Navy needs to address delays at the ICP level. Of the 40 parts in the top-ten lists, 7 appear to have suffered delays because they were not available within the DoD supply system. We inferred that this form of unavailability was the culprit whenever the delay in receiving a part was very lengthy or a part was issued by the depot shortly after the ICP took delivery of a shipment of that part. Note that because we did not have access to historical ICP stock levels for the period covered by our NIMMS data, we do not know whether this inference is indeed correct. Moreover, we were not able to delve more deeply into the ICP data we had acquired or to revisit the ICPs for detailed discussions about these problem parts. However, since almost 17 percent of the parts on the top-ten lists had these problems, continued effort to improve the procurement process at the ICPs is important.

³LCDR Barbara Riester, NADEP Norfolk, personal communication.

⁴A part's *replacement factor* (i.e., the fraction of jobs that require a part) is a measure of the part's frequency of use. Somewhat surprisingly, the maximum replacement factor in our data set was a rather low 0.67 (one part was used in 302 of 451 jobs). Seventy-two percent of the parts were used in under 10 jobs (1521 out of 2109) each. Note that this figure does not include common hardware, gaskets, and similar items that are in the "pre-expended bin" (see the Appendix for more details about these items).

The suspected problem needs to be verified and the causes identified.

Solutions might include proscribing certain unreliable suppliers, pursuing ongoing programs to improve procurement, changing contract types for different types of items, etc. In each case, the cost of the solution will need to be balanced against the problem's importance, a task for which the NIMMS data and the measure of engine days of delay will be important.

3. The quality of the NIMMS data needs to be upgraded to make the data more useful for analysis. One of the reasons for selecting the TF-30 for our case study was the quality of the TF-30 repair parts data: over the period covered by the NIMMS data, transactions were entered through NLMS, which performs a series of checks to verify that the requested item is a valid TF-30 part.

However, even for the TF-30, the NIMMS data had deficiencies that made the analysis difficult. The major deficiency was that a fair proportion of the requisitions for many parts were not terminated with an issue transaction. Other transactions in the data implied that some of these parts demands had in fact been resolved, but identifying these cases required complex programming to ensure that these requisitions were classified correctly. And even then, the time of each such requisition's resolution was almost always uncertain. When there were many of these unresolved requisitions for a part, estimation of resolution dates could skew the computation of engine days of delay upward or downward, causing a part to be flagged as a problem when it actually did not affect many engine jobs or not flagged when it actually was delayed and caused artisans to wait (or opened the door for cannibalization of engines in work).

Additional technical problems include nonstandard usage of some fields even under NLMS (e.g., the use of negative order quantities even though there is an explicit increment/decrement field) and the apparent use of additional requisitions to "remind" the system that the part is still needed. Most of these types of problems could be eliminated by adding appropriate input checks and an unambiguous "item no longer needed" transaction that would serve as a definite termination to a set of transactions not satisfied by an issue. The Navy could then use the NIMMS data to more accurately flag problem parts.

If these quality problems are fixed, the NIMMS data will offer insight into the materiel problem that will be invaluable in finding solutions to the delays. The Navy should consider changes to NIMMS to improve its data quality, focusing particularly

on the problems mentioned above. In addition, any plans for a comprehensive depot information system should include ways to capture the needed types of information.

4. The Navy needs to be able to integrate several diverse information sources if it is to analyze the materiel problem. Since materiel supply problems involve the actions of ICPs, NSCs, and the NIF store, as well as the time stream of artisan demands, it is very valuable to be able to bring together procurement information, stock levels, NIF reorders, and parts demands to try to find *system* problems, as was done with the demand-supply profiles. For our analysis, we acquired data from different sources: Norfolk's NIMMS and APADE, the data system at OCALC, the ASO Contract Data File, and several DISC paper reports. These data differ in format and in the types of information they provide. Serious attention needs to be given to the process of extracting key pieces of information for the use of those who will analyze supply system performance as we have suggested above.⁵ The information needed includes order date, all receipt dates and quantities, and the stock position of the DoD supply system (at least those stocks under ICP control). This information would allow the Navy to focus its attention on the appropriate segments of the procurement and supply processes for those parts that are the pacing items for depot repair. The maximum delay for two-thirds of the engine jobs was caused by only 56 parts, so it appears that the information interchange needed to solve a substantial proportion of the materiel problem could be quite small.

⁵The DoD Corporate Information Management initiative is aiming for much greater standardization in DoD information systems than now exists, perhaps to the extent of having one set of information systems for the wholesale segments of all service supply systems. See *Statements to Congress on Department of Defense Corporate Information Management*, prepared by the Assistant Secretary of Defense (C³I), April 1991.

APPENDIX

ENGINE REPAIR PROCESS AND MATERIEL SUPPORT

OVERVIEW OF PROCESS

Engines that need depot repair ("carcasses") are stored at the local NSC until the depot is ready to start repair. The depot and NAVAIR agree to a quarterly schedule for the number of engines to be repaired; as NAVAIR releases money and the depot has the needed capacity, engines are *inducted* from the NSC warehouse and assigned a unique job number.¹ Workers inspect the engine (often with partial disassembly) and assess the repair needs; then, the various engine components are split up among the engine shops and the repair process begins.

At the end of the process, the engine is reassembled from repaired or replaced components and parts that did not need repair. The engine is then returned to the NSC in RFI status, ready to be sent to the fleet. The repair of components for an engine is usually charged to that engine's job number; however, components are sometimes repaired under a separate depot component repair program that fixes engine components for use by all Navy repair facilities (NADEPs and intermediate-level repair shops at Naval air stations and on aircraft carriers).

HOW ARTISANS WORK

By policy, the Navy does not project needs for repair parts; stock is ordered on the basis of historical demands only. As artisans work on an engine and its components, they request and are issued repair parts. Each part is the responsibility of a single DoD ICP, which purchases the part from vendors, monitors the stocks of that part held by storage points (although visibility is by no means complete), and reorders when those stocks run low.² If stocks do run out, the ICP may help coordinate aggressive measures to get the needed part, including special buys, authorization for local manufacture, or expedited procurement.

¹The engines are not inspected by the depot prior to induction into repair, so the necessary repair work may vary widely from engine to engine.

²This overview greatly simplifies the complex information systems DoD ICPs use to monitor stocks and compute parts needed. Each of the services and DLA have different procedures, although all are variations on classic inventory theory models (e.g., see G. Hadley and T. M. Whitin, *Analysis of Inventory Systems*, Prentice-Hall, 1963).

SOURCES OF PARTS

Artisans actually get parts from three sources. First, each shop has relatively inexpensive hardware known as "pre-expended bin" stock, which includes items such as nuts and bolts, O-rings, etc. These items have a very high usage rate (virtually 100 percent for most items because they are needed for most engine jobs) and are available to the artisan with minimal paperwork. Their issue is not charged to a particular engine job and so is not tracked closely by NIMMS. The occasional problems that arise in keeping these parts in stock are not detectable in the data we used and thus were not considered in our analysis.

The second source of supply is the depot's NIF store. This entity stocks *consumable* parts—i.e., parts that are discarded when broken because they cannot be economically repaired. The NIF store bases its stock levels on historical demand, the goal being to keep a stock sufficient for covering a fixed period of depot operation.³ As is true for pre-expended bin parts, the response from the NIF store to an artisan's demand is very quick, virtually always less than a day *if the part demanded is in stock*.

The last supply source is the local NSC or another segment of the Navy and DoD supply system. An artisan's demand for a part reaches this third level for various reasons. First, the part requested may be a *reparable*—i.e., a part that, unlike a consumable, is repaired if broken.⁴ By Navy policy, the NIF store does not stock reparables, although they may be available from the NSC. Second, the part requested may be a consumable with low demand. The NIF store does not stock such parts. Finally, the NIF store may stock the requested part but be out of it, in which case the local NSC will probably also be out of it. Delays may range from a few days to weeks or months or longer, depending on the priority of the requisition and where the part is in the DoD supply system. If the part is not in stock anywhere in the DoD supply system, it must be procured by the responsible ICP.

³The NIF store inventory policies are under review at this writing.

⁴This distinction between reparables and consumables is often a matter of policy rather than feasibility.